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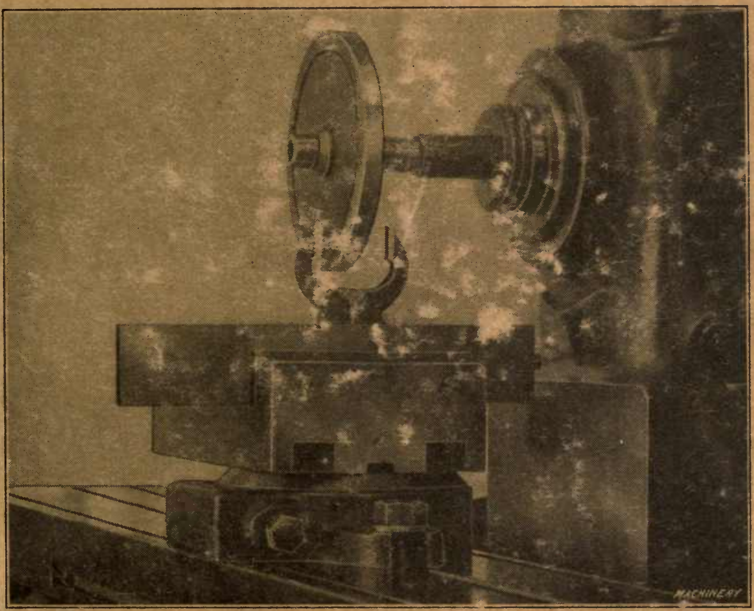
GAGE MAKING AND LAPPING

SECOND REVISED EDITION



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NUMBER 64

GAGE MAKING AND LAPPING

CONTENTS

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In the following pages are compiled a number of articles relating to gage making and lapping. These articles have been contributed from time to time to MACHINERY by various writers. In some cases the opinions expressed differ slightly as to the best practice, each writer describing the methods with which he personally has had most experience or best success. The articles of each writer have been given in full, irrespective of the fact that, due to this, some statements are repeated.

CHAPTER I

PRINCIPLES OF GAGE MAKING*

Possibly there is no branch of tool-making that demands more skill and accuracy than does gage making. Little has been published, however, regarding this exacting line of work; one reason for this is that while the gage maker might describe very thoroughly, in detail, the manner in which to make this or that gage, this detail description may not apply to the methods employed in another shop. The object of this chapter is to touch briefly upon the general principles of the different methods generally in use.

Material for Gages

It is becoming the general practice to make gages from machine steel and case-harden them. Machine steel hardened to a depth of 0.003 to 0.005 inch would seem to answer fully as well as tool steel for gages, because a wear of a small fraction of a thousandth of an inch

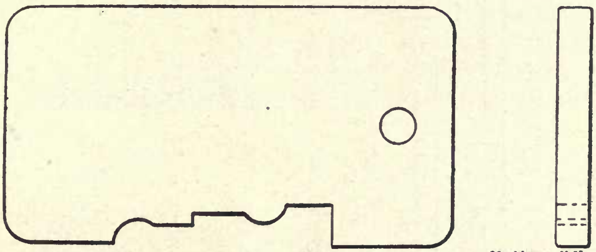


Fig. 1. Profile Gage

would in any case render the gage useless as a standard. To obtain the very best results from plug or ring gages, however, they should preferably be made of tool steel. This is principally because the gage may spring slightly during the hardening process, and if the gage were made of machine steel and hardened only to a depth of 0.003 inch or thereabouts, the case-hardening could easily be lapped away, leaving soft spots in the gage. This not only shortens the life of the gage, but the soft spot would be charged with emery when lapping the gage to size, so that the finished product would be partly gage and partly lap. On the other hand machine steel is superior to tool steel for snap gages and profile and receiving gages, owing to the fact that these gages are not appreciably distorted during the hardening process.

Making Plug Gages

When making plug gages, the best results are obtained by using stock considerably larger than the finished gage size. For instance,

* MACHINERY, June, 1905.

if the plug gage is to be 1 inch in diameter it should be made from a bar of steel 1⅛ inch in diameter or larger. In this way the scale and outer stock that has been decarbonized to a certain degree is entirely removed. The same precaution is applicable to reamers, mandrels, dies and numerous other tools that require hardening. If a plug gage, 1 inch in diameter, were turned from a bar of steel only slightly larger than 1 inch, it would be found after hardening that spots would appear on the surface which would seem to bulge. These spots are hardened, but the surrounding stock is apparently soft. However, if this gage were ground down to 15/16 inch diameter, it would be found to be hardened over its entire surface.

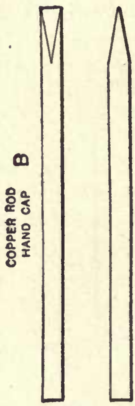
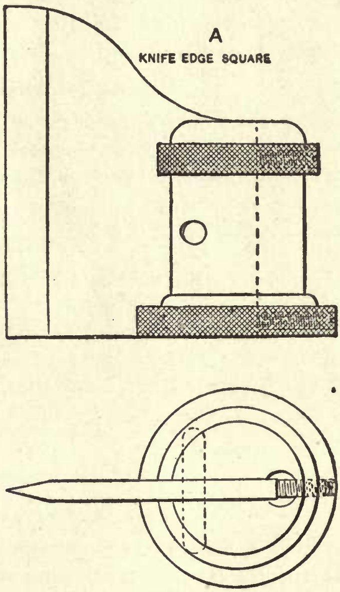


Fig. 2



Machinery, N.Y.

Fig. 3

The methods of making gages vary greatly in different shops, according to the accuracy required. Some manufacturers do not require gages of greater accuracy than those turned and filed nearly to size, after which they are hardened, and polished to size with emery cloth. In other cases it is necessary to grind the gages to size after hardening. Then, again, in another manufacturing plant the requirements may be more exacting and the gages are ground and lapped. Going still further we find manufacturers who are still more exacting, and demand that gages should be hardened, rough ground, aged, finish ground, lapped and the minute ridges caused by circular lapping entirely removed by lapping the gage lengthwise to size. About 0.0001 inch is removed by this operation. The lapping operation is dealt with in detail in Chapter III.

Profiling Gages

When making a profiling gage of the type shown in Fig. 1, it is a good plan to first make a sheet steel templet to accurately fit the model. A planer tool is then fitted to the templet, and the impression is planed through three gages at the same setting, the three gages afterward being used as master, inspector, and working gages, respectively. Should the profile be of such a size as to render it impracticable to plane the entire surface at once, a series of formed tools are made, together with a male templet, and the impression is planed reasonably close to this templet and then finished by hand. As it is absolutely necessary that the profile be the same over the entire surface, the knife-edge square shown in Fig. 3 will be found exceptionally well adapted for this work. The gages, after hardening, are lapped by hand by means of a flattened copper rod and flour emery, so that they will fit the model perfectly. The appearance of this copper rod is shown in Fig. 2. Should the gage open up a trifle during

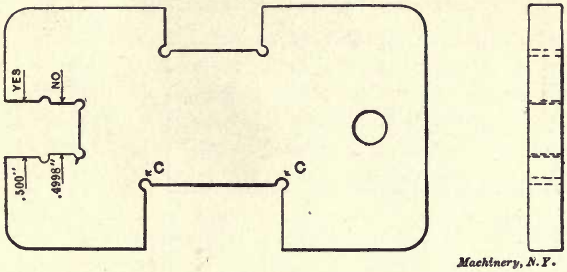


Fig. 4. Common Snap Gage with Clearance for Lap

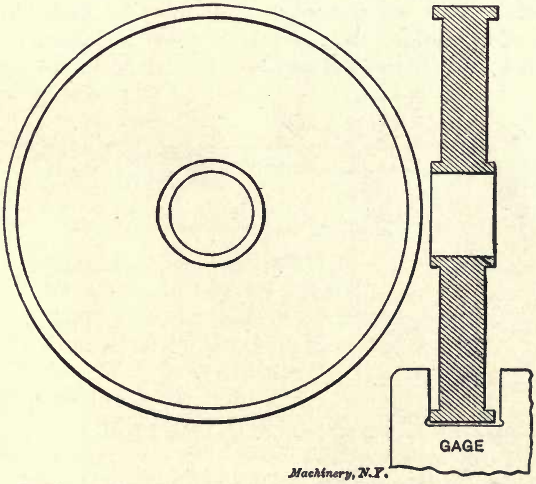


Fig. 5. Cast-iron Lap Adapted to Lapping between Jaws

the hardening process, a common vise will prove an admirable tool for correcting this, as the interior of the machine steel gage is soft.

Snap Gages

The common snap gage, Fig. 4, is carefully machined to within 0.002 inch of the finished size, care being taken to make the faces smooth. The holes *C* are made to allow clearance for the lap, Fig. 5, which is a

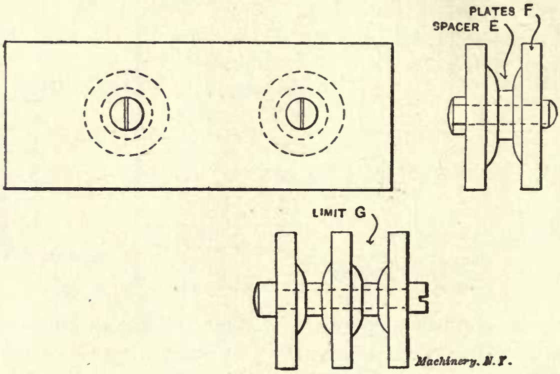


Fig. 6. Easily Duplicated Snap Gage

cast-iron disk. The gage is case-hardened and gripped in the vise of a milling machine, a hand-operated machine being preferably used for this operation. The lap is placed on the arbor, smeared with emery paste, and set in motion. By moving the table back and forth, the gage can be lapped until the model can just be started to enter, after which

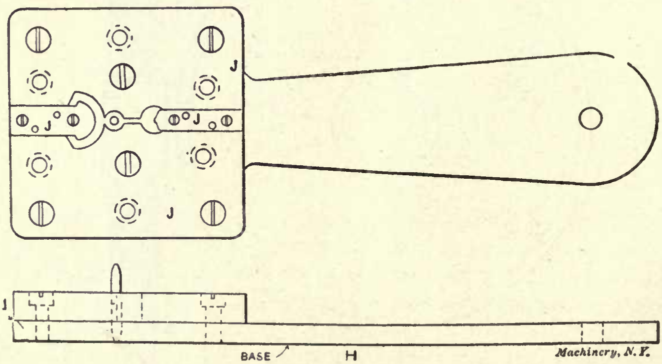


Fig. 7. Receiving Gage

the gage should be finished by hand. If the gage is made to dimensions on a drawing instead of to a model, it is advisable to make a temporary end-measuring gage of drill rod and fit the snap gage to this temporary gage.

Fig. 6 shows a very simple style of snap gage. This type is easily duplicated. In this gage spacers *E* are used which are made to the required size for the piece to be gaged. The plates *F* are parallel pieces of hardened steel which have been ground and lapped. When the gage becomes worn, all that is necessary in order to duplicate the original size is to remove the plates, lap the surfaces true, and lap off the required amount on the spacer. A limit gage can be made by adding another plate and using spacers of proper length as shown at *G*.

Method of Making a Receiving Gage

The receiving gage, Fig. 7, is a very difficult gage to make, and on account of its cost, it is rarely used except where it is absolutely necessary to do so. The gage is made to fit accurately the entire profile of the piece to be gaged, and is made of a series of small pieces fitted together, the object being to overcome as far as possible the distortion of the steel when passing through the hardening process. The

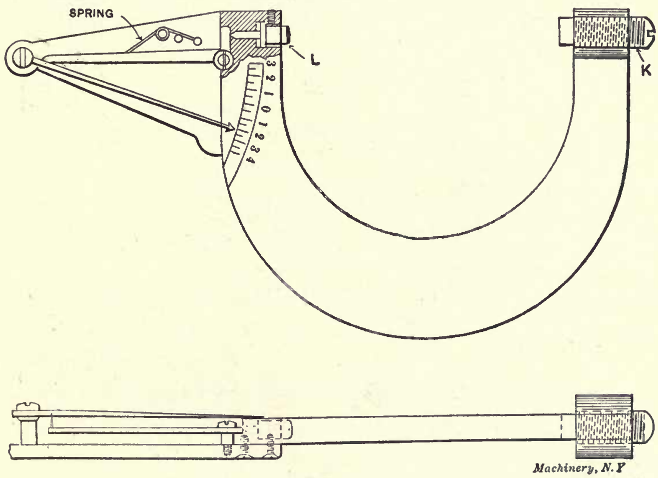


Fig. 8. Universal Snap Gage for Large Work

base *H* is of machine steel, case-hardened, and its upper surface lapped perfectly level. The pieces *J* are ground and lapped on the bottom, and the formed edges are lapped by hand to fit the model. To obtain the best results, fit the pieces *J* to the model while the pieces are soft, and fasten them to the base *H* by screws. The dowel holes are now drilled and tapped with a fine pitch tap, say 5/16 inch diameter, 32 threads per inch. After the pieces *J* and the base are hardened, soft steel screws are turned securely into these holes and dressed off flush with the top and bottom of the pieces *J* and the base. After the pieces are lapped to fit the model, they are tightened in their places, and the soft screw bushing drilled and reamed through for the dowels. It is impracticable to attempt to lap dowel holes true, especially when they are tapered and do not line up. This soft screw bushing will be found useful on many other tools where dowel holes are apt to change during hardening.

Making a Universal Snap Gage

Fig. 8 shows a universal snap gage that is designed especially for large work. All that is necessary to make one gage cover a wide field is to set the gage to the required diameter (from standard length rods, so that the pointer stands at zero), then as the gage hangs on the piece to be gaged, it is swung so that anvil *L* passes over the highest point, and the pointer will record 200 times greater than the actual error. Any one who has used a large micrometer for measuring such work as is found in arsenals knows the difficulties under which one is obliged to obtain measurements. One man will hold the micrometer on the breech of a large gun and another man will do the measuring. With this form of gage one man can measure very handily, as all that is necessary to do is to note the number of graduations traversed by the pointer when the gage passes over the work.

CHAPTER II

THE MANUFACTURE OF GAGES*

The introduction of our present gage system was made necessary by the development of our modern methods in the manufacture of interchangeable parts; a complete system of gages is absolutely essential to the accurate and economical production of interchangeable parts in large quantities. Some manufacturers have been slow to recognize the necessity of absolute interchangeability in their products. This has been particularly true of some machine tool makers; who has not seen half a dozen lathes of one make and pattern in the same shop where not even chucks were interchangeable?

Probably no class of manufacturers has more fully realized the necessity of absolute interchangeability than the makers of small firearms, and to gun makers is due much of the credit for the development of gaging systems and the training of highly efficient gage-makers. The standard methods adopted by them can, with slight modifications, be adjusted to fill the requirements of any manufacture; but the slow adoption of gaging systems is largely due to the manufacturer's prejudice which is often strengthened by ignorant or incompetent foremen who decry anything that savors of improvement, impelled by motives of fear that any innovation might carry beyond the narrow groove of their capabilities.

Principles of Development of a Gaging System

The manufacturer who contemplates the establishment of a gaging system must use the greatest care in the selection of his designer, for the question of economy hinges on the experience, foresight and ingenuity of the latter. The designer should be a man familiar with shop methods, and must be on good terms with the men with whom he must cooperate. In this way he will be able to gather considerable information which will be of great assistance to him in the production of efficient results.

The designer must satisfy himself that each piece being machined is handled to the best advantage, and that each cut or operation is in proper sequence. Having done this he can then lay out his gages in such a manner that each operation will have its own equipment, independent of other operations, thus insuring uninterrupted progress of the work.

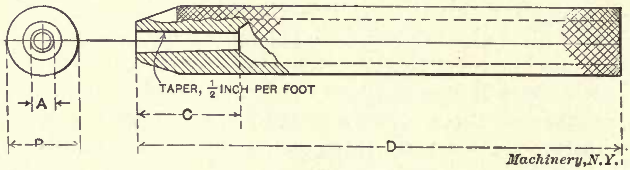
In machining parts intended to be interchangeable it is necessary first to establish certain working points which are maintained throughout the entire series of operations. In some cases the working point must be shifted during the progress of the work, through

* MACHINERY, September, 1909.

the creation of a more important point after the taking of some cut, or the necessity of cutting away the original point. Very often two holes (not always necessary to the completion of the work), drilled and reamed in the piece, are used for locating it on pins inserted in the various jigs and fixtures, thus bringing each piece in like relation to the cutting tool after the proper setting has been established. And, again, it is sometimes found expedient to use one hole, and one surface, or one end and one side as holding points, and the designer must ever bear in mind that he must gage from the same point from which the piece is located or held, whenever it is possible to do so, although, of course, there are exceptions to this rule.

Should the parts on completion of the machining operations be required to pass through a system of inspection, before being as-

TABLE I. PLUG GAGE HANDLES



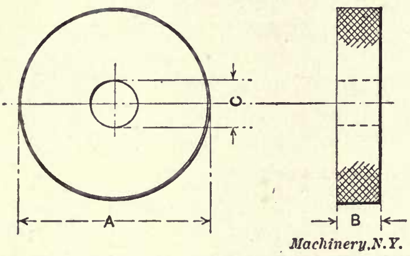
No.	A	B	C	D
	Inch	Inch	Inch	Inch
0	solid	5/16	1/2	2
1	0.120	3/8	1/2	2 3/4
2	0.205	1/2	3/4	3
3	0.245	1/2	1	3 1/4
4	0.345	5/8	1	3 1/2
5	0.445	3/4	1	4
6	0.545	7/8	1 1/8	4

sembled as a whole, which is the custom in some lines of manufacture, the gage designer is confronted by an entirely different set of conditions. He has then to do with the finished piece, and does not consider the intermediate stages. He should study the mechanism of the assembled machine, and must understand the function of each piece, and the relation it bears to all other parts; then first will he be able to produce gages which will correctly test the vital points, with accurately established limits of tolerance.

The next essential to the economical inspection of parts is to limit the number of gages to as few as possible; when considering that parts are often made in lots of from 5000 to 50,000, and each piece is to be inspected, the importance of this will be readily understood. It is *common* practice to combine gages of the simpler forms, such as a series of snap gages, or snap and profile gages, on the same plate; or a number of ring gages inserted in a plate also bearing snap or even profile gages. It is not, however, *good* practice to combine profile gages with any other type, as their longevity is much greater than that of any other form.

It is on the manufacture of the simple, but much used plug and ring gages we shall treat in this chapter, not with the old-time machine shop conception of a gage, as something unquestioned (but often questionable) as to accuracy, to be locked up in the boss' desk and brought forth only on state occasions, and given out with many so-

TABLE II. RING GAGE HOLDERS



No.	A	B	C
	Inch	Inch	Inch
1	$1\frac{1}{8}$	$\frac{1}{4}$	$\frac{5}{16}$
2	$1\frac{1}{4}$	$\frac{5}{16}$	$\frac{7}{16}$
3	$1\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$
4	$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{5}{8}$
5	$1\frac{7}{8}$	$\frac{11}{16}$	$\frac{7}{8}$
6	$2\frac{1}{8}$	$\frac{11}{16}$	$1\frac{1}{8}$

licitations for its care, and its safe return; but as something made in quantities, to be used, worn out and replaced.

The Making of Plug Gages

Our earliest, and in some cases, our latest, recollection of a plug gage, is an unwieldy affair, either knurled or fluted on the handle end, and made of solid tool steel throughout, expensive to make and clumsy to handle, requiring much valuable stock in the making, and

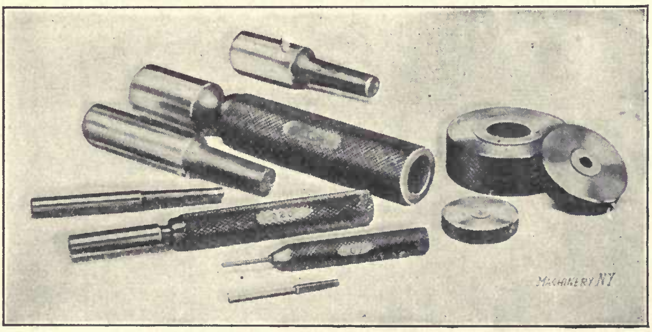


Fig. 9. Plug and Ring Gages of Approved Construction

extreme care in the tempering (although the latter is always commendable as the danger of water cracks is always imminent). However, we now have a much improved design not only convenient to handle and symmetrical in form, but comparatively inexpensive to make, and with the risk of loss in hardening reduced 20 to 50 per cent. This last depends first on the compact design, separate from the handle, and secondly, on the small amount of time expended up to the point of hardening, thus reducing the pecuniary loss when breakage does occur.

Although the designs of these gages, as produced by various makers, differ slightly, the fundamental principle is the same, *i. e.*, to insert the plug proper into a handle from which it can be easily removed, and replaced by another if desirable. The most popular, cheapest and

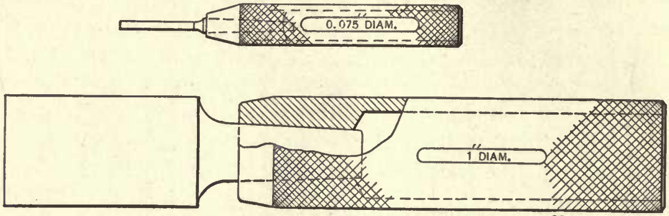
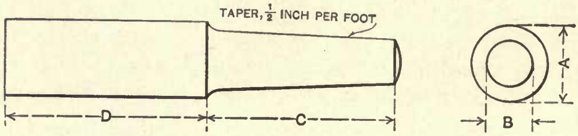


Fig. 10. Plug Gages and Handles

best form, adaptable to plugs from 0.075 inch diameter upwards, is that with the taper shank. These plug blanks are made on a screw machine from drill rod or bar stock, by simply turning the taper shank and cutting off to any desired length, usually ranging from ¾ inch to 2 inches on the straight part. They are then centered for

TABLE III. PLUG GAGE BLANKS



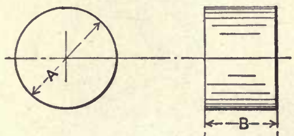
No.	A	B	C	D	No of Handle
	Inch	Inch	Inch	Inch	
1	⅛	0.100	⅝	¾ to 1¼	1
2	3/16	0.150	⅞	1 to 1⅝	2
3	¼	0.200	1¼	1 to 2	3
4	⅜	0.300	1¼	1⅛ to 2	4
5	½	0.300	1¼	1⅛ to 2	4
6	¾	0.400	1¼	1¼ to 2	5
7	⅞	0.400	1¼	1¼ to 2	5
8	1⅛	0.400	1¼	1½ to 2¼	5
9	1⅜	0.500	1⅜	1½ to 2¼	6
10	1⅝	0.500	1⅜	1½ to 2¼	6
11	1⅞	0.500	1⅜	1¾ to 2½	6

turning, grinding and finishing the straight portion, no further work being necessary on the shank. A number of such gages are shown in Fig. 9.

Knurled handles as shown in Fig. 10 are made in standard sizes, each accommodating a certain range of plugs. These handles, being of machine steel, can be turned out very cheaply on a hand or automatic screw machine, when, after stamping size or other desirable marking on a spot flatted for that purpose, they can be blued if desired. They are then ready to receive the plug, which is simply driven lightly into the taper end, and when necessary, can be easily driven out from the rear.

Plugs ranging in diameter from 0.075 inch down, should be made from straight hardened wire, which need not be ground, but simply lapped to size, and sweated into the handle, which can be made in the same manner as for the taper shank plugs, but with the front end left solid, and afterwards drilled to suit any desired size. This method of inserting in the handle obviates the necessity of centering, turning or grinding, and the solder will be found sufficiently strong to withstand the torsional strain on a plug of small diameter. As the breakage of these small plugs is quite frequent, this will be found a very cheap and satisfactory means of production. The wire

TABLE IV. RING GAGE BLANKS



Machinery,N.Y.

No.	A	B	Finished Hole	No. of Holder
	Inch	Inch	Inch	
1	0.350	0.300	0 to 0.150	1
2	0.475	0.350	0.150 to 0.300	2
3	0.600	0.400	0.300 to 0.400	3
4	0.725	0.500	0.400 to 0.500	4
5	0.975	0.750	0.500 to 0.750	5
6	1.225	0.750	0.750 to 1.000	6

can be bought in a great variety of sizes, and for any given size of plug, wire should be used 0.001 inch larger in diameter, which will be sufficient allowance for the lap to clean up any surface irregularities.

The taper shank plugs ranging in diameter from 0.075 inch upwards, are handled differently. When the blanks are made from bar steel, they should be at least 0.080 inch larger in diameter than the required finished size, as this will insure turning off the decarbonized surface of the bar, and reaching the more uniform structure beneath. In the case of those made from drill rod but half of this amount is necessary. After centering with a small center reamer (large centers should be avoided as they sometimes induce water cracks), the plugs are turned smoothly to within 0.005 inch to 0.010 inch of the finished size, according to length, and carefully hardened.

As plugs require extreme hardness, it is only necessary to reheat them sufficiently to relieve the strain after hardening, excepting those of slender diameter, which should be drawn reasonably low—about spring temper—at the intersection of the shank and body, to prevent them from snapping off while inserted, should any side strain be exerted on the handle. With the use of a little fine emery mixed with sperm or lard oil applied to a simple cast iron or copper lap, pointed similar to a lathe center, and held in the chuck of a hand lathe, the centers are then lapped preparatory to grinding.

The three most desirable results in grinding are straightness, smoothness of surface, and closeness to finished size. When a good regular grinder is available the best results can be obtained, particularly if it is equipped for wet grinding; for then a piece can be ground to within 0.0002 inch of the final size, with the assurance of a perfectly smooth and even surface. An emery wheel of about No. 80

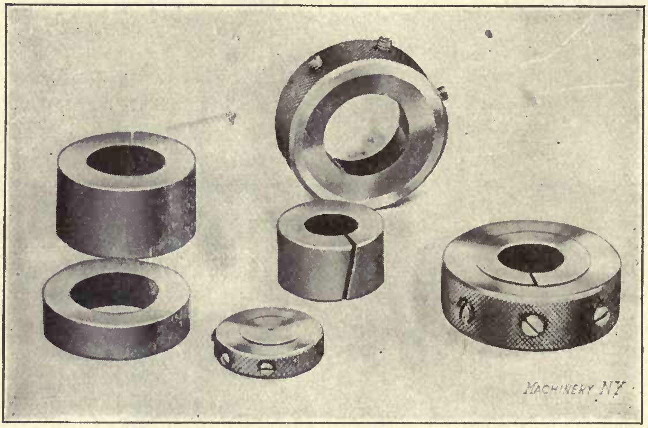


Fig. 11. Lap and Lap-holders used for Making Plug Gages

grade, with the cutting surface reduced to 1/8 or 3/16 inch in width, and kept from glazing or clogging, gives very satisfactory results.

For the benefit of those wishing to do work of this kind, and not having a regular grinding machine at their disposal, it might be said that usually 0.001 or even 0.0015 inch is not too much allowance for lapping when the work is ground in a bench lathe or other contrivance not made specially for this work. Under such conditions it is difficult to get any but a rough and uneven surface. Before grinding, the piece should be looked over carefully for cracks; those not discernible on the closest scrutiny will make their presence known in the process of grinding or lapping, but at whatever stage they develop, the piece should be immediately scrapped. Should the piece develop a tendency to run eccentric after the surface has been once trued or cleaned up by the grinding wheel, it evidently is cracked.

The object of lapping work after grinding is to give the extreme smoothness necessary to a lasting surface, and the minimizing of friction, and to correct any slight irregularities caused by the grinding wheel or due to imperfections in the grinding machine, as well as to perfect its straightness.

For plug and ring gage work, cast iron makes the best lap, and although it cannot be charged with abrasive as readily as copper or lead, it gives much better results, besides wearing much longer than the other metals. Laps for lapping plugs are made from disks ranging from 3/16 to about 1/2 inch in thickness, are drilled and reamed to

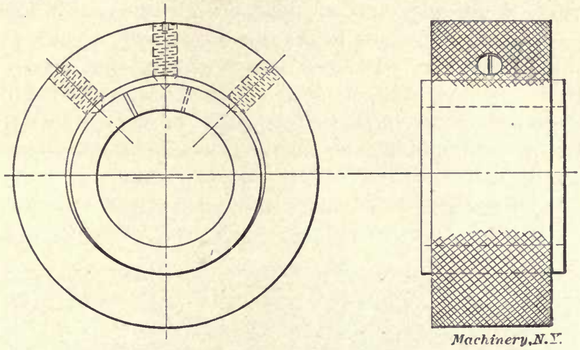


Fig. 12. Design of Lap and Lap-holders for Making Plug Gages

a sliding fit on the ground plug, and split on one side to allow of adjustment, as shown in Figs. 11 and 12. The holders, made in a few standard sizes to accommodate the different disks, are of machine steel, knurled, and having three adjusting screws to enable the operator to regulate the tension of his lap.

The piece to be lapped should be running at the speed required in grinding, which varies according to diameter, and the lap adjusted at

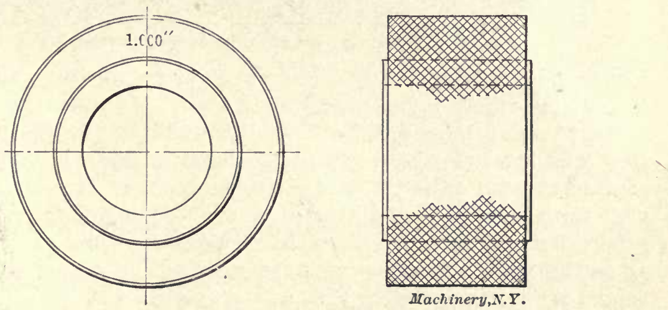


Fig. 13. Approved Construction of Ring Gages with Holders

all times to grip firmly on the surface, but sufficiently free to allow its being held by the fingers. In the case of large work a wood clamp can be used. As the piece revolves, the lap is slowly drawn back and forth from end to end, and under no circumstances should this oscillation cease while the plug is in motion.

The proper abrasive to use in this operation is flour of emery, or a very fine grade of carborundum; the latter, being the faster cutter, seems more desirable. It is mixed with sperm or lard oil, to the consistency of molasses, and applied sparingly to the surface being treated, from whence it is taken up by the lap, which becomes charged as it passes over after each application.

As the operation is almost completed, however, this is discontinued, and a drop or two of oil charged with the finest particles of flour emery is substituted. This is obtained by sifting as from a pepper shaker about a tablespoonful of flour emery into a tumbler of lard oil, when, after standing an hour, the oil should be poured off, and will be found charged with the finest emery, the coarse particles having settled to the bottom. This abrasive is applied a drop at a time from the end of a small pointed stick or wire, and will make a remarkably smooth and bright finish. To the practiced hand, it requires very little time to lap a piece in this manner.

Should it be necessary to remove any quantity of metal by the lapping process, much faster methods can be employed, such as lead or

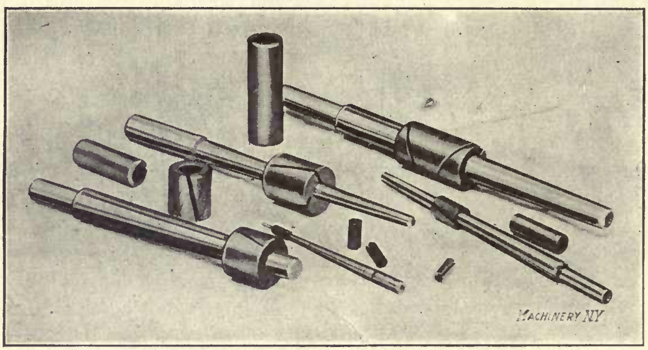


Fig. 14. Lap and Lap Arbors used in Making Ring Gages

copper laps charged with a coarse abrasive liberally applied; but the results will be found hardly satisfactory if accuracy is desired.

Should there be any hitherto undiscovered soft spots in the piece, they will invariably show up in the lapping, as their duller color is contrasted with the rest of the harder surface. However, it is possible for a piece to be slightly soft throughout, and finish up uniformly bright, but the softness should be discovered by file or other test at an earlier stage. In either case the piece can only be rehardened, and reworked for some smaller size, as a plug gage with a soft spot on its surface is useless.

Ring Gages

When ring gages are to be made in quantity even when the quantity is small, they should be made from tool steel disks turned to certain standard diameters and cut from the bar. These blanks can be kept in stock, as well as the holders (see Figs. 9 and 13) into which they are forced after being drilled, reamed and hardened. The holders are made on a screw machine, of machine steel, requiring only to be turned, knurled, drilled and reamed with a slightly smaller hole than the diameter of the corresponding gage blanks, and cut off to length. They can be treated similarly to plug handles as to marking and bluing, as occasion demands; they can be used indefinitely by replacing the ring bushing when worn.

The gage blanks are drilled and reamed, or bored, to within 0.002 or 0.003 inch of the finished size, care being taken to have the hole as straight as possible. In handling for hardening they are wired around the outside with a short piece of soft iron wire, to afford a

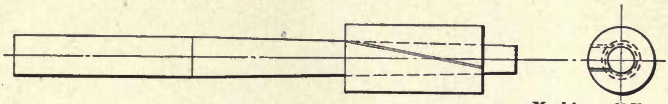


Fig. 15. Design of Lap and Lap Arbors for Making Ring Gages

means of handling and avoid the contact of tongs, or the necessity of passing a rod through the hole in dipping, as this latter has a tendency to cause bell mouth by retarding the action of the water within the hole. After hardening they are at once reheated sufficiently to relieve the strain, as in the case of plug gages. They are then ground on an arbor, allowing about 0.0015 inch to insure a tight fit in the holder, and are then rough lapped to within 0.0005 inch of the finished size, pressed into place, and finish lapped. The ends can be ground while on the arbor or on a surface grinder when in the holder, but before the finish lapping.

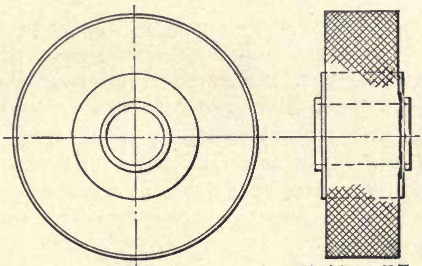


Fig. 16. Master Ring Gage with Small Collar at Mouth of Hole, which is Ground off just before Completing the Lapping

If the rings are sufficiently large to require grinding they should first be ground on the periphery to the proper diameter, and then on the inside to within about 0.001 inch of the finished size. As holes ground with a wheel are liable to be slightly tapering, they cannot safely be worked as close as a plug, in the grinding. It is an unnecessary expense to wheel grind rings up to ¾ inch diameter, as simple lapping gives equally good results and requires much less time.

The form of lap used (Figs. 14 and 15) is a cast-iron cylinder with a taper hole, split diagonally on one side to allow of expansion as it is forced on a taper arbor, to compensate for the gradual enlarging of the hole being lapped. The lap should be about three times the length of the ring it is intended to be used in. The same rules regarding abrasive, speed, etc., apply as in the lapping of plug gages, but care should be exercised to avoid a too generous application of the abrasive as the process nears completion, for, if applied too lavishly, the particles have a tendency to crowd under the edges and cause a bell mouth effect. This latter trouble is sometimes eliminated by making the rings with a slight collar on each end (see Fig. 16), which is ground off after the rough lapping has been completed; but this is somewhat expensive, and except for master rings, hardly necessary.

In the making of small ring gages which do not allow the insertion of a substantial cast iron lap, a tool steel lap charged with diamond dust can be used. This abrasive, which is not extensively used outside the watch factories and concerns doing work of like nature, must be used to be appreciated. It can be purchased as Brazilian bort, in a pebbly form; crushed in a suitable mortar, and graded to suit requirements; it is particularly applicable to hand or form laps, or laps for delicate or sharp corners. It is also a very rapid and smooth cutter, economical and lasting, and is readily taken up and retained on the surface of a tool steel lap to which a very small quantity is applied mixed with sperm oil, and rolled in with an extremely hard roll. Occasional rechargings are necessary as the work progresses, but in the intervals a drop of sperm oil is used on the lap.

Should it be required to make master or reference plug and ring gages, a somewhat different course should be followed than for gages intended for continual use. The method is about the same in each case, but with the former, after hardening, the work should be carried along at intervals, over a considerable time. First the rings should be cleaned up on the grinder and laid away, and later ground again, and so on during the course of a year, or even longer, where future requirements are being anticipated. This allows the metal to set, or as called by some, to season.

The Measuring and Fitting of Plug and Ring Gages

In factories not equipped with a measuring machine, some sort of standard should be adopted to which each and every workman can adjust his measuring tools. As few men measure alike, the disadvantages of varied adjustment are added, and the result is hardly conducive to uniformity. A first-class gage maker has in his kit reserve micrometers, which are properly adjusted to the standard of his employer, and used only for reference or final measurements. This allows him to work to a remarkable degree of closeness before presenting his work for test should a measuring machine be employed for that purpose; and where it is not, the work is usually inspected by one man, equipped with no better means of measuring than the maker's, but who serves to unify the element of touch which varies with different workmen.

Where master plug and ring gages are desired in pairs, the plug is first made to measurement, and the ring is then made and fitted to the plug. When trying the ring on the plug during the final fitting, both should be wiped perfectly clean and allowed to acquire like temperature, by lying together on a bench, or machine, or for a few seconds in cold water. The plug is then given a slight coating of rancid oil, and inserted in the ring, into which it should be a close wringing fit. When fitted properly this way, it will be found impossible to insert the plug, should the oil be removed, or even when some other kinds of oil are substituted. This rancid oil is simply the drippings of animal oil that has been used many times on some drilling or cutting operation; the older it is the better.

Should a number of plug gages of one size be required for manufacturing purposes, they should all be made to machine or micrometer measurement. It is utter folly to try fitting any quantity of plugs to one master ring if absolute uniformity is essential, particularly if they are of any considerable length, owing to the tendency of the ring to wear in the fitting. One of each lot can be tested to the ring to make sure that it conforms to the proper standard.

Ring gages, whether made singly or in quantity, are fitted to a master plug, which, as it wears, is comparatively inexpensive to replace, the wear being easily detected by occasional reference to the master ring.

CHAPTER III

LAPPING FLAT WORK AND GAGES*

The main essential points of the art of lapping can be described in a book, but, the same as with any other line of mechanical work, it is necessary that the workman shall do considerable lapping before he can become proficient. There are certain motions, touches, sounds, refinements, etc., which the skilled workman acquires by practice, that are impossible of enumeration and description, or of enumeration and description that would be intelligible to an inexperienced man. For instance, ask a carpenter how he knows that he is sawing a board straight, and he will be unable to tell you. Nevertheless

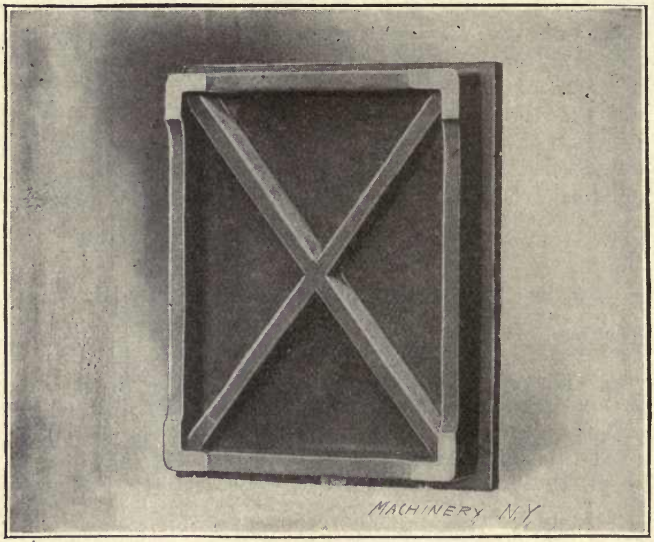


Fig. 17. Back of Standard Flat Lap, showing Ribbed Construction

he has acquired a peculiar sense of touch, or such general acuteness of the senses, that he knows instantly when the saws starts to "run out." His mind and arm automatically, as it were, return the saw to a straight line without missing a stroke. It is the same way with a die maker. He can file a die, looking only at the surface line, and can detect the instant when his file "rocks" from a straight line. He will tell you that he "feels" it, but is unable to define what the sensation is. Likewise, one cannot explain some of the finer points in the art of lapping, and can only point out those which are fundamental, and which must be acquired first by the workman unaccus-

* MACHINERY, November, 1907.

tomed to such operations. He must acquire the refinements by practice and experience.

A Perfect Lap Required for Perfect Lapping

The first requisite of perfect lapping is a perfect lap, and right here is where the novice will make his first mistake, that is, in the preparation of the lap. To make a surface lap, it should be carefully planed, strains due to clamps being avoided, and then it should be carefully scraped to a standard surface plate. This is done by rubbing the face of the lap on the standard surface plate and scraping down the high spots until a perfect plane surface is obtained. If a standard surface plate is not at hand, a lap can be made level by using three laps that are nicely planed and used alternately as follows: We will number the laps Nos. 1, 2, and 3. Now, rub No. 1 and No. 2 together, and scrape the high spots until they fit. Then introduce No. 3 and scrape it down to fit No. 2, and then to fit No. 1, and so on. The third lap eliminates the error that might follow if only two laps were used. For example, it is possible to fit two plates accurately together without making them plane surfaces, one becoming concave and the other convex. The third lap absolutely prevents this and produces a perfect plane surface if time and patience hold out. It is a slow operation, but not so slow as trying to lap a piece true with a lap that is not true.

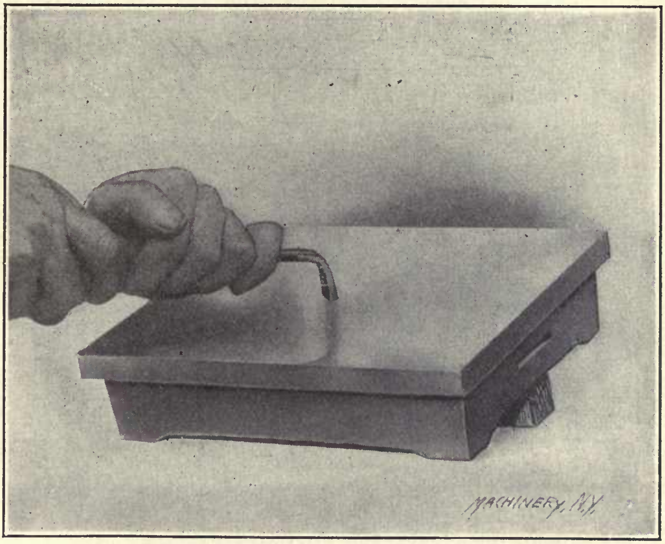


Fig. 18. Scraping Down the High Spots

The Objection to Ground Laps

The laps may be ground together instead of scraping, but the writer prefers the scraping process, as it is easy to see when the job is done.

It is also better to scrape them, because it is quicker than attempting to grind them level with the fine grade of emery that is required for nice lapping, and it must be remembered that when ground together the laps *are already charged.* Hence, the necessity of using a fine grade of emery if they are ground together.

Using a Hand Surface Lap

The writer prefers a cast-iron lap, Fig. 17, thoroughly charged, and having all loose emery washed off with gasoline. When lapping, the surface is preferably kept moist with kerosene, although gasoline causes the lap to cut a trifle faster. It evaporates so rapidly, however, that the lap soon becomes dry, and the surface caked and glossy in

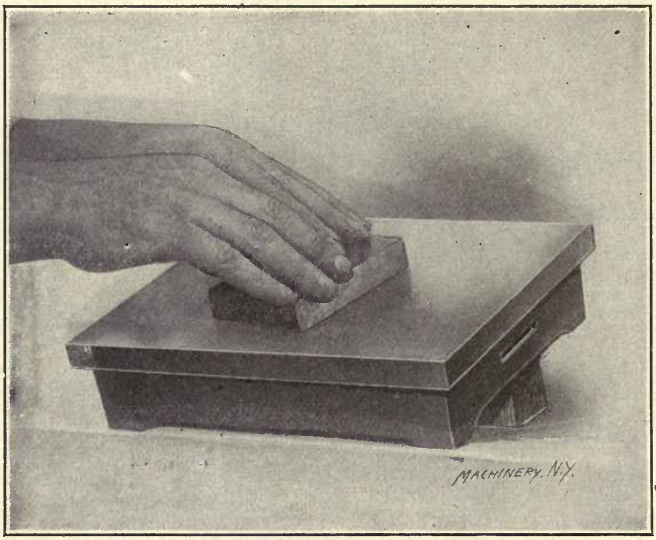


Fig. 19. Charging the Lap, using a Hardened Steel Block

spots. When in this condition, a lap will not produce true work. The lap should be employed so as to utilize every available part of its surface. Gently push the work all around on its surface, and try not to make two consecutive trips over the same place on the lap.

Do not add a fresh supply of loose emery to a lap, as is frequently done, because the work will roll around on these small particles, which will keep it from good contact with the lap, causing poor results to follow. If a lap is thoroughly charged at the beginning, and is not crowded too hard, and is kept well moistened, it will carry all the abrasive that is required for a long time. This is evident, upon reflection, for if a lap is completely charged to begin with, no more emery can be forced into it. The pressure on the work should only be sufficient to insure constant contact. The lap can be made to cut only so fast, and if excessive pressure is applied, it will become "stripped" in places, which means that the emery which was imbedded in the lap has become dislodged, thus making an uneven surface on the lap.

Causes of Scratches—Grading Emery

The causes for scratches are as follows: Loose emery on the lap; too much pressure on the work which dislodges the charged emery; and what is, perhaps, the greatest cause, poorly graded emery. To produce a surface having a high polish free from scratches, the lap should be charged with emery or other abrasive that is very fine. The so-called "wash flour emery," sold commercially, is generally too uneven in grade. It is advisable for those who have considerable high-class lapping to do to grade their own emery in the following manner: A quantity of flour emery is placed in a heavy cloth bag, and

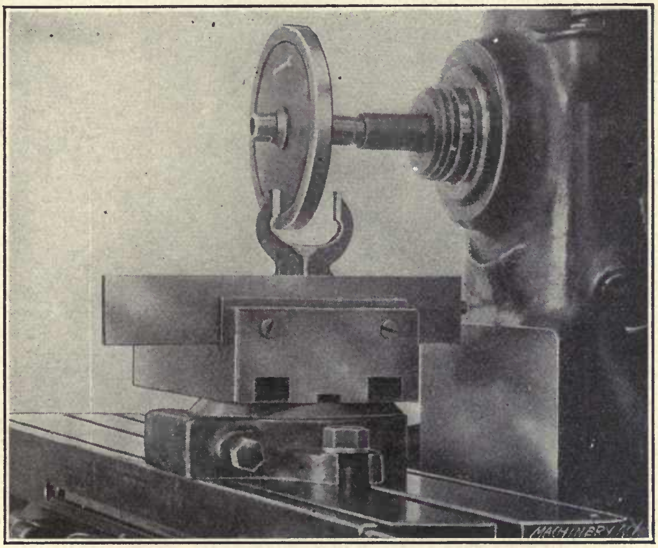


Fig. 20. Lapping a Gage

the bag gently tapped. The finest emery will work through first, and should be caught on a piece of paper. When sufficient emery is thus obtained it is placed in a dish of lard or sperm oil. The largest particles of emery will rapidly sink to the bottom, and in about one hour the oil should be poured into another dish, care being exercised that the sediment at the bottom of the dish is not disturbed. The oil is now allowed to stand for several hours, say over night, and then is decanted again, and so on, until the desired grade of abrasive is obtained.

For the information of those not well acquainted with grading abrasives, it may be said that the grade of diamond dust known as "ungraded" is obtained in about five minutes, while it requires about three weeks to obtain the grade known as No. 5, which is very fine. But, even at the end of three weeks, there still will be small particles in the oil that have not settled, due to the viscosity of the oil.

To lap true and free from scratches, one must have skill and be thoroughly conversant with the peculiar sounds, touches, and motions spoken of above. For a high polish on work, a rapid motion and slight pressure are necessary for success. It is also necessary that the lap is properly charged with properly graded abrasive.

Lapping Gage Jaws

Fig. 20 shows the best method that has come to the writer's notice for lapping the jaws of gages. The lap is made of cast iron and is relieved as shown, leaving only a thin edge or flange on each side to bear against the jaws. As the machine table is worked back and

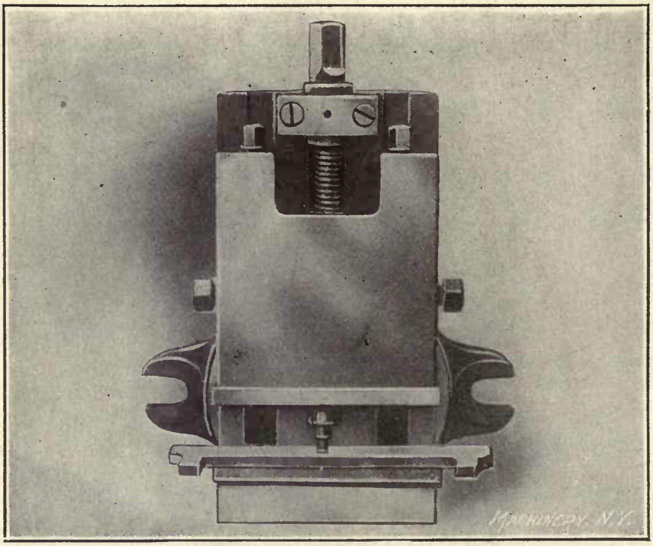


Fig. 21. View of Machine Vise, showing a Gage Clamped without Springing it

forth, the lap passes over the entire surface of the jaw, grinding it down in the same manner as would be done with a cup emery wheel. Care must be taken to clamp the gage in the vise so as not to spring it. Fig. 21 illustrates an approved method for holding a gage so that the vise jaws will not deflect it. Should the gage be sprung, it is clamped at the center only, leaving the ends free. Snap gages are now mostly made of machine steel and pack-hardened. Made in this way they do not change much, as the interior of the gage is left soft, and whatever change occurs can be easily remedied, but in any case, the method illustrated is the safest one to follow, for it leaves no doubt as to the gage being held free from spring during the lapping operation.

A lap should be turned on the arbor on which it is to be used, for it is almost impossible to put a lap back on an arbor after it has been removed, and have it run true. Therefore, the lap should be recessed quite deeply, as shown, to allow for truing up each time the lap is placed on the arbor. Perhaps when the lap is mounted on an arbor in the milling machine, it will be found to run out not more than 0.001 inch, but that means that it is touching the work in only one spot, and the result can be hardly better than if a fly-cutter was used for a lap. Fig. 22 shows the operation of truing the lap. A keen cutting tool is clamped in the vise and in this way the lap can be trued as nicely as though it were done in the lathe! In fact, it is superior, for there is absolutely no change in the alignment of the lap with the work spindle after it is turned, which might easily happen should it be turned in the lathe and then mounted in

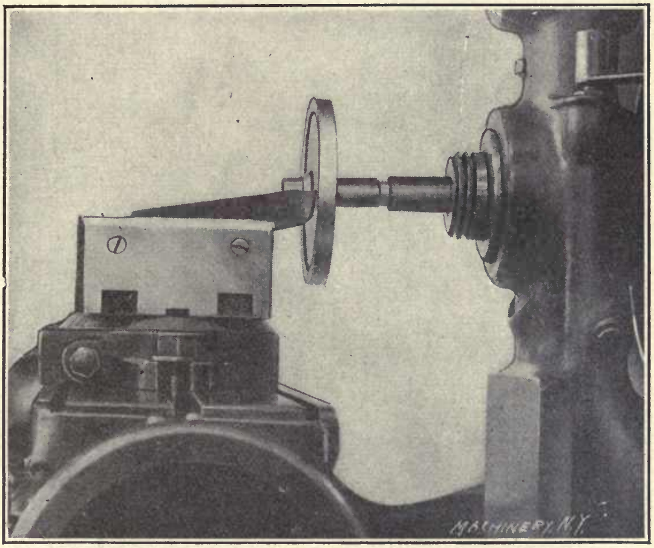


Fig. 22. Truing the Lap with a Tool held in a Vise

the milling machine spindle. With a perfectly true lap, a perfect contact between the lap and gage is insured for its entire circumference. Both sides of the lap should be turned at the same setting on the arbor.

Fig. 23 shows the operation of charging a circular lap, using a roller mounted in a suitable handle for the purpose. The emery is rolled in under moderate pressure. It is good practice to make the roller of hardened steel, and after charging the lap, all the surface emery should be thoroughly washed off.

The next step is to square up the jaws of the gage. Do not depend on the zero marks of the vise. The jaws of the gage may have sprung a little in hardening, and if the zero marks of the vise are depended upon to square the work, there possibly will not be sufficient stock on the jaws to clean up. Be very careful to set the gage by the surface of the jaws and to clamp it in the vise as previously noted, so that it is under no pressure tending to spring it out of shape.

When employing a power-actuated lap, the little instrument shown in Fig. 24 is useful in determining the instant when the lap touches the work. By placing the forked end on the work and the wooden part to the ear, the sound is greatly magnified, and it makes it much easier to determine the precise point of initial contact. If one depends upon the naked ear to tell when the lap touches the work, he is liable to crowd the lap too much, and scratch the work or strip the lap. With this instrument the mechanic will know the instant the lap just touches the work, and this is the position where its work should be done. In short, the lap should nct work under any

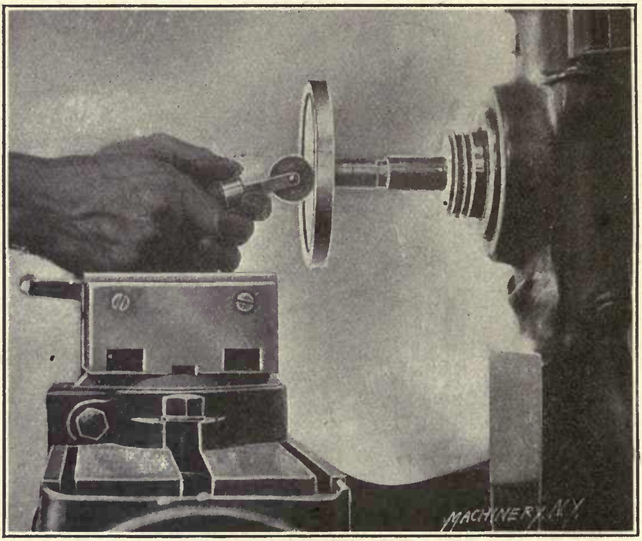


Fig. 23. Charging the Lap with a Roller

appreciable pressure, but should simply touch the work. Hence the desirability of some means of magnifying the sound and not depending on the naked ear.

The workman should avoid the custom of adding a fresh supply of abrasive to the lap, as it is not only injurious to the character of the product, but it naturally increases the time required for lapping. To illustrate the action, suppose that an arbor is to be ground in a grinding machine, and that it is belted so that it runs with a wheel at the same speed. The consequence will be that no grinding action could take place, as there would be no difference in motion. The condition is very similar when loose emery is placed on a surface lap. The emery simply rolls around between the work and the wheel, and occasionally a piece of emery is imbedded in the lap long enough to scratch the work. While it may look as though the lap was cutting much faster, the truth is that it cuts slower and produces poor work.

In lapping jaws, some workmen round-lap, and then finish by hand, but a better job will result when finished in the machine. It is poor practice to rough-lap a gage, using a coarse grade of emery, and then wash the lap and smear it with fine emery. Of course the lap is already charged with a grade of emery last used, and the act of putting on a supply of fine emery on the lap will not produce as good

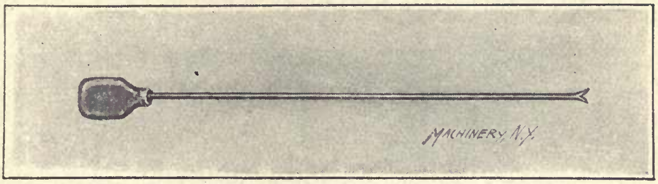


Fig. 24. Sound Magnifier

a surface as if the gage were finished without the fresh supply of emery, although the latter is of a finer grade.

Lapping Gages*

Assume that a 1-inch plug gage is to be lapped to size. Such a gage needs only about 0.0015 inch for lapping. The outside lap, shown in Fig. 26, should be made of cast iron, copper, or lead, and the holder *D* should be provided with adjusting screws. The flour emery used should be sifted through a cloth bag to prevent any large particles of

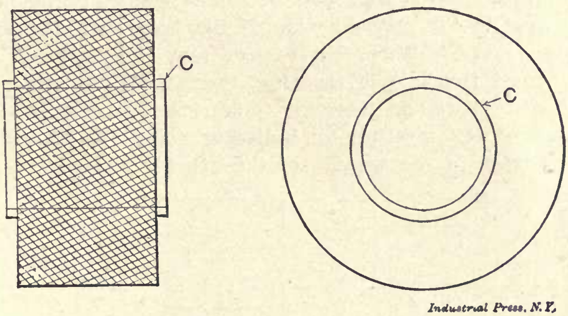


Fig. 25. Ring Gage to be Lapped

emery entering the lap and scratching the gage. After sifting the emery it is mixed with lard or sperm oil to the consistency of a thin paste. The gage is then gripped in the chuck of the lathe by the knurled end and smeared with emery paste. The lap is adjusted to fit snugly on the gage and the lathe is speeded up as fast as possible without causing the emery to leave the gage. The lap requires constant adjusting, to take up the wear of the lap, and reduction in size of the gage. When measuring the gage, it should be measured at

* MACHINERY, May, 1904.

both ends and in the center to make sure that it is not being lapped tapering. When the gage has been lapped to within 0.0002 inch of the finished size, allow the gage to thoroughly cool and then by hand lap lengthwise of gage to the finished size. By so doing all minute ridges that are caused by circular lapping are removed, thereby leaving a true surface and also imparting a silvery finish. A gage should never be lapped to size while warm (heated by the friction of the lap), because the gage expands when heated, and if then lapped to size it will contract enough to spoil it.

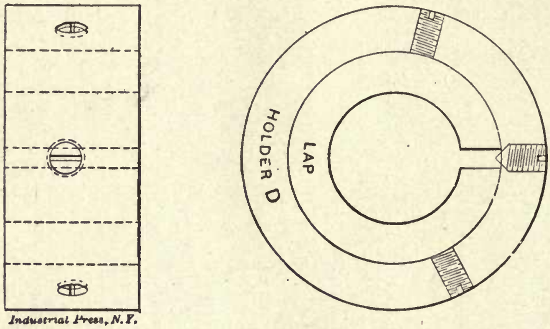


Fig. 26. Outside Lap

In grinding out the inside of a ring gage considerable difficulty is experienced in adjusting the grinder so that it will grind straight. One way to prove the straightness of a hole being ground is to move the wheel over to the opposite side of the hole until the wheel will just barely "spark." Then, beginning from the back of the hole, feed out, and if the hole is tapering, the wheel will either cease to spark, or will spark considerably more. Another and better way is by means of the multiplying indicator gage, Fig. 28. By fastening the indicator to the spindle of the grinder and placing the contact pin of the indicator on the opposite side of the hole and feeding in and out, the pointer will record in thousandths of an inch just what the deflection is.

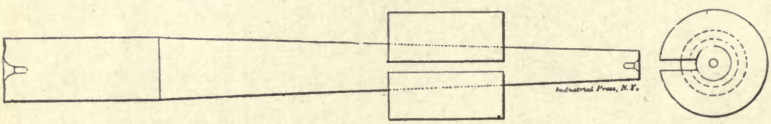


Fig. 27. Inside Lap

A ring gage should be made as shown in Fig. 25, the object being to prevent the gage becoming "bell mouthed" while lapping. After the gage is finished, the thin projecting web *C* is ground off, leaving a good straight hole. The lap used for inside work is shown at Fig. 27. The lap can be made to always fit the gage by merely forcing the lap further along on the taper arbor; the lap being slotted allows it to expand. In making a ring gage having a taper hole or a taper plug gage, it is necessary to employ a different method of lapping, as it is impossible to lap a taper hole with a taper lap. The facts regarding lapping are these: First, the lap must fit the hole at all times; secondly, the lap must constantly be moved back and forth. Therefore, if a taper lap is made to fit the taper hole it will lock and not revolve. If held in one place the lap will quickly assume the uneven surface of the hole. If the operator attempts to lap a

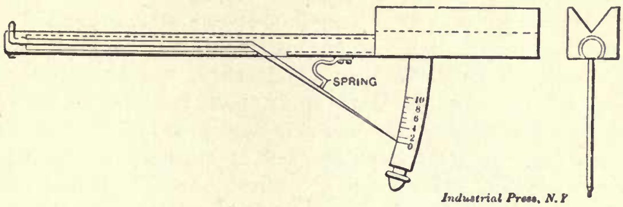


Fig. 28. Indicator for Testing Truth of Holes

taper hole by constantly revolving the gage on a straight lap he will surely dwell longer in one place than another, thereby making a hole that is anything but round. The following method is, therefore, used: Having ground the hole to size, plus allowance for lapping, then, without disturbing position of slide rest or grinder head, change the emery wheel for a lap made of copper—of the same shape as the emery wheel with the exception of having a wider face—and lap in the same manner as the hole was ground, care being taken not to "crowd" the lap.

CHAPTER IV

THE ROTARY LAP*

In Fig. 29 is shown a rotary lap 24 inches in diameter, intended to run at a speed of about 300 revolutions per minute. The engraving will give a clear idea as to the construction. Some men think that if the lap has a true, flat surface, any one can produce true work, but such is not the case; it requires considerable skill, and that skill can be acquired only by long practice. Many machine operations can be shown to another person and the principle grasped readily, but not so with lapping. A great deal of skill is required in lapping thin pieces, small straight-edges or long narrow bars. It is possible, and requires no skill at all, to lap a thin piece of steel, convex or concave, by using a little more pressure in one place than another, and if the surface of the lap is not kept sharp it will soon heat and warp the work out of true. For a rotary lap kerosene and gasoline used together give the best results; but a hand lap should always be used dry. Keeping the surface of the rotary lap straight and true is very important and requires good judgment in using it. The outer edge runs so much faster than the inside that it is obvious that if it is used too much, either in the middle, inside, or outside, hollow places will be worn in the surface, so that it is a good plan to use the lap all over and try the surface frequently with a straight-edge, favoring the high places when using it.

The rotary lap is charged by sprinkling carborundum over the surface when not in motion, and then pressing it in by rubbing with a piece of round iron held in both hands. An old pepper box with a perforated top is just the thing to use for sprinkling carborundum.

The lap in Fig. 29 is made of an ordinary cast-iron disk *A* with ribs on the bottom and anchor grooves on the top. It is also provided with a hub and a shaft. The end of the shaft supports the whole weight of the lap and runs on a hardened convex disk. A coating of lead is cast over the surface of the lap, and then hammered to make it compact. A galvanized iron pan *B* is provided, the edges of which project above the surface of the lap to prevent the liquid, or whatever is used, from flying off, and onto everything around. Another handy device on this lap is a bar which is provided with ways and a sliding head *C* which can be pushed from the outer edge to the center of the lap. The bar is fastened to lugs which project on opposite sides of the frame, and can readily be removed when not in use. The bar is also provided with adjusting screws to set it parallel with the surface of the lap or to set the sliding head square with the surface. The sliding head has a square corner and an angle

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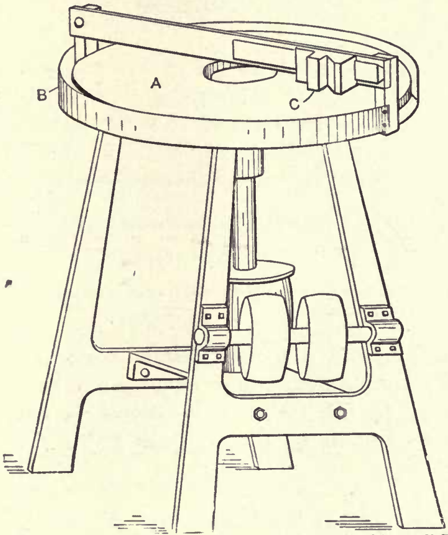
* MACHINERY, August, 1908

groove which can be used for lapping the ends of round or square pieces.

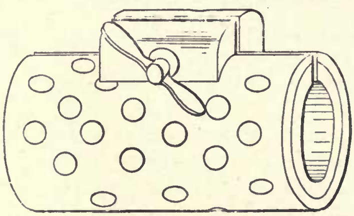
The engraving Fig. 30 shows a good way of making a lap for cylindrical work in the lathe. A piece of wrought iron pipe about 2 inches long, with a number of 5/16-inch holes drilled through will answer the purpose. Face one end of the pipe so that it will stand level on



Machinery,N.Y.

Fig. 29. The Rotary Lap

a surface plate; wrap a piece of heavy paper around the outside, using rubber bands to hold it on, then form a lug out of pasteboard and clamp that on any side of the pipe so that several of the holes open into it; secure a mandrel the same size as the piece to be lapped, twist a piece of string in a spiral around the mandrel, insert it in



ery,N.Y.

Fig. 30. Lap for Cylindrical Work

the center of the pipe, and pour the molten lead in. When cool, drive out the mandrel and proceed to drill and tap a hole for a thumbscrew in the center of the lug; then slit one side through the center of the lug with a hack saw, and file off all sharp edges and burrs so that it will not injure the hands. In lapping, the faster the lap is drawn back and forth over the work the more nearly straight it will be, and as the lap wears and works easy, the thumb-screw is given a slight turn to keep it in contact with the work.

A very handy tool, which is shown in Fig. 31, is almost indispensable in doing work with the rotary and hand laps; it is a home-made

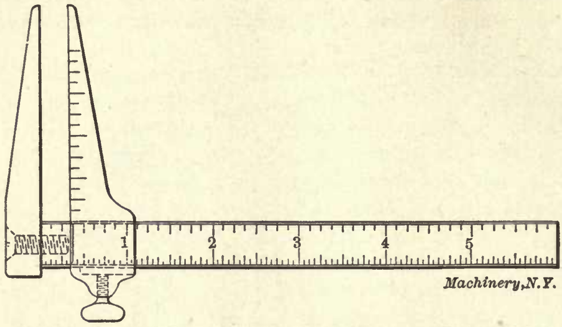


Fig. 31. Tool used for Lapping when Sizing Duplicate Parts

caliper square. The taper between the hardened jaws is 0.001 inch in the whole length, and a 6-inch flexible scale is inserted in the beam. One jaw is graduated, which enables one to see how far the piece will slide up in the jaws. This caliper is not used so much for accurate measurements as for accurate sizing for parallelism or duplicating sizes.

CHAPTER V

MISCELLANEOUS LAPS AND LAPPING OPERATIONS

The laps which are shown in the accompanying illustrations are, according to an experienced tool-maker, excellent designs for both the outside and inside lapping of cylindrical parts. At *A*, Fig. 32, is shown an inside lap with the arbor in place. The included angle of the taper of this arbor should be about 2 degrees; this is considered great enough for any kind of work. The lap proper, or the part that is in contact with the work, is made of bolt copper, and is shown in detail at *F*. Cast iron and lead are sometimes used, but copper is the best metal for hardened work. The lap is split as shown, to allow it to expand as it becomes worn. The length of the lap should be somewhat greater than the length of the hole to be operated on, and the thickness *B*

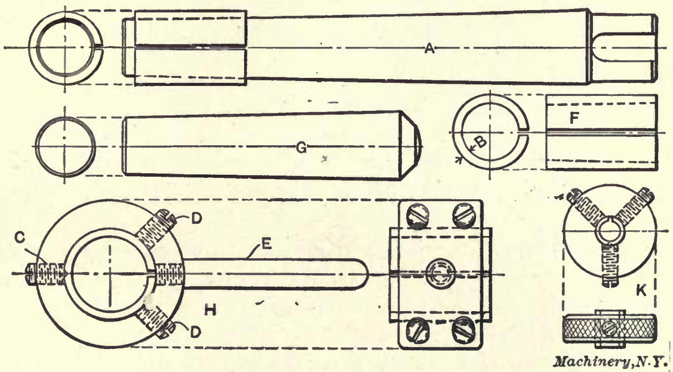


Fig. 32. Laps for Inside and Outside Work

should not be more than 1/6 or less than 1/8 of the diameter of the work.

When making these laps, especially small ones, a hardened swedging plug (shown at *G*), ground to the same taper as the arbor, can be used to advantage for tapering the hole through the lap before it is turned and slotted. If in the operation of lapping, the hole becomes "bell mouthed," that is, enlarged at the ends, this is caused by the introduction of sharp emery from time to time as the hole is being lapped. To obviate this, the lap should be cleaned of all loose emery and expanded by driving the arbor farther into it. The hole is then dry lapped by using only the emery that sticks or is charged in the lap. This process must be repeated occasionally until the proper size is obtained. If the operator is careful to see that the emery used is not too coarse, and the lap is kept expanded to fit the work at all times, the result will be a perfectly straight hole. It takes considerable practice before one can use a lap and keep it from getting lumpy. If this occurs, the high spots must be removed with a file, and the lap kept a close fit to the work. The work should always be finished to size with the lap dry and well fitted to it.

At *H* is shown an outside lap. The proportions of the lap proper should be the same as were given for inside laps. The same method of procedure described for inside work should also be followed, *viz.*, the lap must be freed from oil and loose emery from time to time as the work progresses. The pointed screw *C* keeps the lap from slipping out of place, and the adjusting screws *D* compress it to fit the work. A handle *E* should be used on all laps of large size, as it will be found much more convenient than a lathe dog, which some workmen use for moving the lap. At *K* is illustrated an outside lap and holder for small work, say, less than ½ inch in diameter. Laps of this

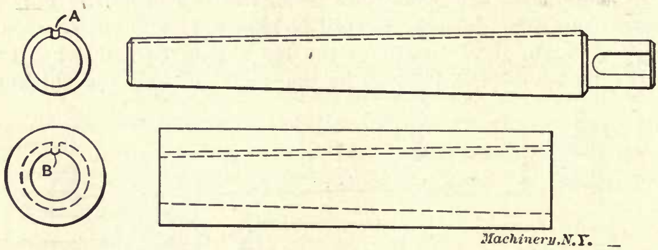


Fig. 33. Lap Arbor and Lead Lap with Driving Key

size are not provided with a handle, but are knurled on the outside as shown.*

It is the experience of many tool-makers, however, that copper is not a metal to be quickly and accurately worked. The method just outlined, therefore, would, perhaps, not be practical in a shop where nearly every hole is finished by lapping—by all classes of workmen. The split lap, as shown at *F*, might expand and revolve on the arbor, possibly causing particles of emery to become loose and lodge in the work, especially if it were of brass or aluminum. This style of lap and method of holding is therefore suitable only for very small tool work, but even then it is expensive. In consideration of these difficulties, and in view of the fact that accurate lapping is a very difficult operation for many machinists, the views of another tool-maker of long experience are given below.

Lapping is not, he says in an article in MACHINERY, as difficult as it would seem, providing the proper methods and tools are used in the process. The material used for holding the abrasive is one of the most important factors when the work is soft; and it is very important that this material should be softer than the work, which would make it easier to charge. In shops where nearly every hole

* F. P. Crosby, MACHINERY, February, 1910.

is finished by lapping, lead has been adopted as the best known metal to use. It is inexpensive and can be remolded by apprentices; besides it charges very quickly, which is a much desired and important feature.

The lap arbor illustrated in the upper view in Fig. 33 is used for holding the lead laps, which may be molded in as many sizes as desired. The molding arbor should be an exact duplicate of the working arbor. A small groove *A* is milled the entire length of the molding

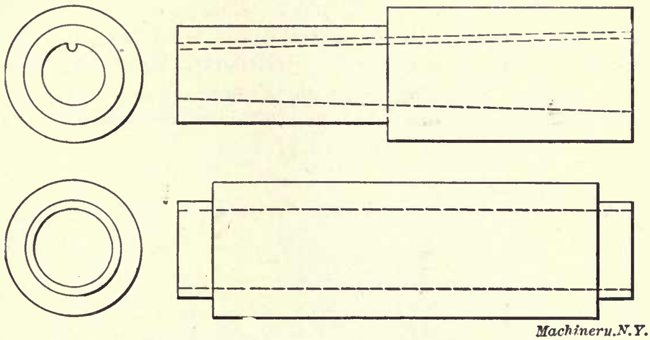


Fig. 34. Lead Lap with Two Diameters; Method of Preventing Bell mouthed Holes

arbor, producing a driving key *B* (see lower view, Fig. 33), which fits the working arbor. This driving key is very necessary, as it is almost impossible to prevent considerable lap friction between the work and the lap. Without the driving key, the lap would surely revolve on the arbor and become tight in the work.

It is very convenient to have laps with two or more diameters, as shown in the upper views in Fig. 34, which enables the operator to

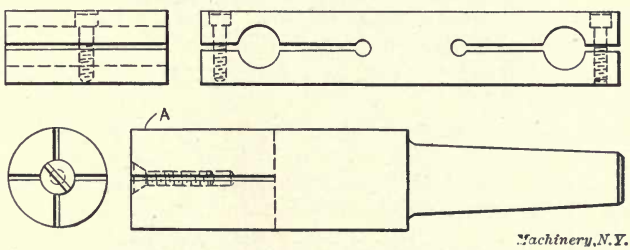


Fig. 35. Adjustable Cast-iron Lap; Form of Lap for Blind Holes

readily find a size without a waste of metal for each job. It may be necessary, of course, to slightly reduce one of the diameters to obtain the desired size. The usual custom is, when a lap is a little too small, to flatten it between two parallel plates in an arbor press, which forces the metal outward on the open sides.

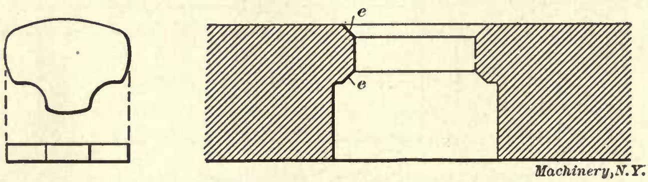
The lower view in Fig. 34 shows a method of preventing a "bell mouthed" hole (large at the ends). A shell about 3/16 inch long is left on each end of the work, which is cut or ground off after the lapping is finished. This will remove the bell mouthed part, which is otherwise practically unavoidable. The causes of a bell mouthed hole are as follows:

1. Too much loose emery and oil at the mouth of the hole, which assists in cutting faster.

2. Lapping too long in one position, causing the cutting medium inside the hole to become dull, so that the abrasive which is outside, being sharp, cuts faster.

3. Lap arbor under-size, not straight, and too long. When possible, the contact portion of a lap should be shorter than the work, which will greatly assist in preventing a taper hole.

For outside lapping or "wringing" a cast-iron adjustable lap is used, similar to the one shown in the upper view in Fig. 35. Any piece of



Figs. 36 and 37. Punching to be Swaged, and Section of Die

cast iron will do, but it is much better to have special castings of several sizes for this purpose, with holes in each end as shown. The slots and holes serve to hold the loose particles of the abrasive.

The lower view in Fig. 35 shows the style of lap to use in a hole which bottoms, or does not extend through the piece to be lapped. It is slotted and tapped for an expansion screw, which makes adjustment very easy. The slots hold the loose particles of abrasive. This style of lap is usually made of cast iron, and has a taper shank which is fitted to the drill press or lathe spindle. With it a hole which bottoms can be lapped straight, as the point of contact on the lap extends back from the end about ¼ inch to a point *A*; beyond this point it is slightly tapering.*

Lapping a Sizing and Swaging Die

In a certain shop a die was required for swaging and burnishing pieces of mild steel which had been punched to the shape shown in Fig. 36. These pieces measured about one inch long, across the wide part, ¾ inch the other way and they were about 5/32 inch thick. As they were rough after being blanked out in the press, a die was needed for sizing and burnishing the irregularly-shaped edges. A sectional view of this die is shown in Fig. 37. The hole through it was made perfectly straight for about ⅝ inch from the top, the remainder of the hole being relieved or enlarged as shown. The two edges *e* were then beveled sufficiently to leave about 5/16 inch of the hole straight and smooth. The die was made as hard as possible around the hole, after

* MACHINERY, May, 1910.

which it was heated just enough to ease any internal strains which may have existed. As the hole shrank quite a little it was necessary to lap it to size.

Three cast-iron laps of the shape and size the hole was to be, were made for this operation. These laps, which are shown in Fig. 38, were two inches long and were provided with a ⅝-inch round shank about one inch in length. Two of the laps, *A* and *B*, were slotted, one across the wide part and one across the narrow way as shown. The third lap *C* for finishing, was left solid.

A small Dwight-Slate drill press which was in the shop was used for the lapping operation. One of the split laps was first caught in the drill chuck and the lapping done by working the spindle lever by hand. This method, however, proved too slow so it was decided to rig up the

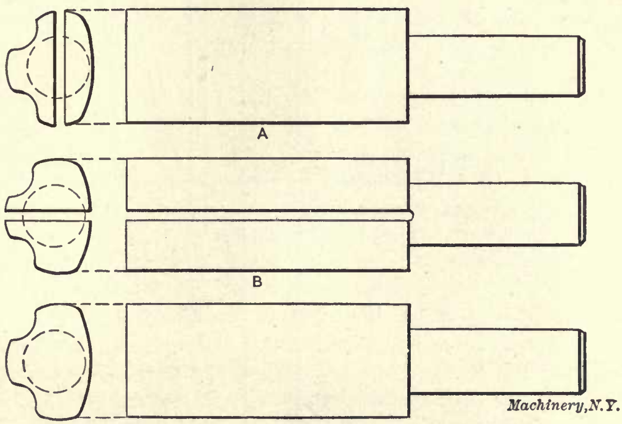


Fig. 38. The Three Laps used for the Die shown in Fig. 37

drill press so that the reciprocating movement necessary could be obtained by power from the machine. The way the required motion was transmitted from the driving pulley shaft to the spindle of the machine is shown in Fig. 39. A crank *A* was attached to the shaft and this was connected to the arm *C* by rod *B*. As the pulley shaft only projected ⅛ inch beyond its bearing, it was necessary to drill and tap it for a ⅝-inch stud on which to mount the crank. Lever *C* was attached to the screw or stud in the spring-case *D*.

After the parts were connected, the die was placed on two parallel strips on the drill press table. The lap was held in the drill chuck as before, and the lapping done by using carborundum flour and oil as an abrasive. It will be seen that with the driving pulley connected to the drill spindle as shown, the latter is given a vertical movement up and down. The slotted laps *A* and *B*, Fig. 38, which were expanded by the use of wooden wedges, were used first. By changing the split laps and using first one and then the other, the hole was soon lapped practically to size. The solid lap was then used to finish the hole, which completed the die.

Those who have not had experience in die work might be interested in knowing how these laps were made. First the approximate center of a sample punching was found, and a 3/8-inch hole drilled through it. Then an end was turned on the rough cast-iron laps to fit the hole and long enough to go through the punching. A smaller hole 1/8 inch in

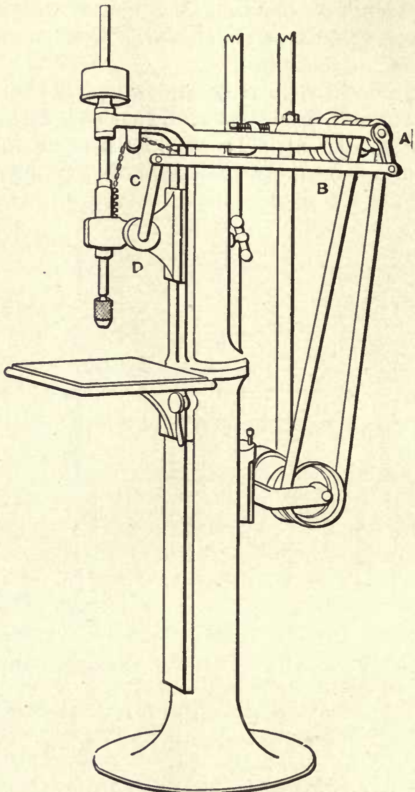


Fig. 39. Drill Press arranged to Give Reciprocating Movement to Spindle for Lapping

diameter was then drilled and into this a pin was inserted to hold the punching in place. The lap was then inserted between the centers of the milling machine and milled approximately to the required shape, the sample being used as a guide. In this way the laps were roughed out so close to the required shape that little filing was needed.

Making Surface Plates by Lapping with Carborundum Grains

Any toolmaker who has had experience in different shops will admit that he has met with difficulties more than once in trying to find a suitable surface plate for laying out work or for scraping a piece to a bearing. Surface plates are regarded in many of the smaller shops as expensive luxuries, although it is recognized that they are a valuable asset in the production of accurate work. To make a surface plate when there is no master plate to scrape to is an expensive operation, as three plates must be made in every case. While two surfaces can be scraped to a bearing so accurately that one will lift the other by cohesion, either one of them if tested on a master plate might appear convex or concave. In the case of three plates, No. 1 and No. 2 are first scraped together, then No. 2 and No. 3, and then No. 3 and No. 1 and so on, until perfect planes are obtained.

To scrape a sixty per cent bearing on three plates, obtaining true planes, is a long and expensive operation, and it is no wonder that the average shop foreman is not very enthusiastic about attempting it, as he knows very well that not one machinist in a hundred has had the necessary experience at this class of scraping to turn out a good job in a reasonable length of time. Accurate surface plates can, however, be made in a surprisingly short time if the following method is employed:

First rough off the surface and the feet, taking off at least three-eighths inch to make sure that all the surface iron is removed. This will prevent warping. Then drill and tap the holes for the handles. The plates should then be allowed to season for at least two months to allow the internal strains to permanently adjust themselves. To finish the plates, all that is necessary is a small amount of carborundum grains for lapping the plates together. Before starting to lap, stamp the plates No. 1, No. 2 and No. 3, respectively. Lay No. 2 on the bench, sprinkle some No. 36 carborundum grain over it, add a little coal oil, and lap No. 1 with it, using a circular motion, and constantly changing the relative position of the upper plate until something like a finished surface is obtained. Then lap No. 2 and No. 3 in the same manner, then No. 3 and No. 1, and then do the whole operation over again. By this time reasonably plane surfaces should have been obtained. Then repeat the procedure, using No. 60 carborundum grain. Then use No. 120, and follow this with No. 220 for the final finishing. The result will be three surface plates with perfectly true planes, a good finish, and a 100 per cent bearing. If the lapping has been carefully done, these plates will lift each other by cohesion.

Many will argue that this method of lapping plates together will so charge them with the abrasive material as to make them unfit to use with fine tools. However, when it is considered that cast-iron holes in accurate watch machinery are lapped to a bearing, and put to every-day use without wearing out the spindles or shafts that run in them any sooner than those used under the same conditions but not lapped, it is doubtful if surface plates can be loaded with abrasive material to such an extent as to make them unfit for use with fine tools. The writer has himself used this process for making plates 12 inches square, having a surface ½ inch deep, and with a base of the regular ribbed construction.

Grading Diamond Dust

The grades of diamond dust used for charging laps are designated by numbers, the fineness of the dust increasing as the numbers increase. The diamond, after being crushed to powder in a mortar, is thoroughly mixed with high-grade olive oil. This mixture is allowed to stand five minutes and then the oil is poured into another receptacle. The coarse sediment which is left is removed and labeled No. 0, according to one system. The oil poured from No. 0 is again stirred and allowed to stand ten minutes, after which it is poured into another receptacle and the sediment remaining is labeled No. 1. This operation is repeated until practically all of the dust has been recovered from the oil, the time that the oil is allowed to stand being increased as shown by the following table, in order to obtain the smaller particles that require a longer time for precipitation:

To obtain No. 1—10 minutes.	To obtain No. 4—2 hours.
To obtain No. 2—30 minutes.	To obtain No. 5—10 hours.
To obtain No. 3—1 hour.	To obtain No. 6—until oil is clear.

The No. 0 or coarse diamond which is obtained from the first settling is usually washed in benzine, and re-crushed unless very coarse dust is required. This No. 0 grade is sometimes known as "ungraded" dust. In some places the time for settling, in order to obtain the various numbers, is greater than that given in the table.