GRINDING AND LAPPING

TOOLS, PROCESSES AND FIXTURES

A Practical Treatise and Toolmakers' Reference Work upon Precision Grinding and Grinding Processes, the Preparation and Use of Abrasives, Lapping Processes and Methods, the Construction and Use of Laps, and the Design, Construction and Application of Fixtures for Grinding Accurate Repetition Parts of Steel and Iron; together with the Automatic Hardening and Tempering of Interchangeable Tool Steel Parts of Delicate Structure, and Percentages of Carbon, Necessary in Steels used for Various Tools and Parts, and which are Afterward Subjected to Grinding and Lapping Processes

By JOSEPH V. WOODWORTH

Author of: "*Dies, Their Construction and Use*," "*Hardening, Tempering, Annealing and Forging of Steel*," "*American Toolmaking and Interchangeable Manufacturing*," "*Punches, Dies and Tools for Manufacturing in Presses*"

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SECTION II

LAPS AND LAPPING; CONSTRUCTION AND USE OF TOOLS AND PROCESSES FOR FINISHING GAGES, TOOLS, DIES AND MACHINE PARTS TO ACCURATE DIMENSIONS.

Requirements for Lapping

A LAP is a tool composed of copper, brass, lead or other soft metal, and sometimes of wood. It is usually a rotating disk or plug. It is used as a conveying agent in applying a cutting or polishing powder of emery, diamond dust or other suitable abrasive, in the cutting of gems and glass, the polishing of cutlery and in the reducing of hardened steel and machined cast iron surfaces to accurate dimensions.

Now, while it is of the utmost importance that the mechanic understand thoroughly the manipulation of machine tools; that he be familiar with approved processes, methods and means for machining steel and iron, and also that he possess sufficient skill to work very accurately with metal-cutting tools, there are also other processes which he must have a good working knowledge of in order to construct perfect gages, and measuring instruments, or to reduce machine parts and tools of precision to accurate dimensions.

He should have a knowledge of hardening and tempering, understand the action of high carbon steels under heat treatment, and know the most approved methods for quenching steel after the heat treatment. Of this we treat fully in Section IV.

The most important process necessary to the production of work as accurate as that referred to above is that of lapping, for upon this depends the efficiency and longevity of the tool or part. If the lapping is not properly done, all work that has gone before — no matter how accurately and carefully accomplished — will go for naught. Therefore a knowledge of this process, possession of skill in the use of the tools, and a comprehension of the variety of designs of laps and their adaptability for work of different classes and various shapes, are absolutely essential to the gage maker, the tool maker and the constructor of precision machinery.

In the following pages are taken up the most approved lapping processes, together with the design, construction and use of laps employed in various grinding departments of up-to-date shops. The methods and designs treated represent the most advanced practice.

Laps

Laps — judging from what we have seen — seem to be among the tools in the machine shop that are pretty generally neglected, except in shops where so much use is made of them that they are an actual necessity. There are few machine shops in which laps of some form, at some time or other, are not used, and if a set were kept in the average shop, a satisfactory use would be made of them.

We have proved this several times, on jobs where the lapping of holes and spindles or plugs was a large part of the work, and where, after a good stock of laps had accumulated, we were continually being asked by different workmen who had pieces requiring to be lapped, if we had this or that size of lap.

A man would come to the bench with a careworn and anxious expression upon his face, and in his hand, perhaps, a cutter just hardened or a piece with a hole in it he had bored in the lathe as near as he could to the required size. It seemed to be all right in the chuck or upon the face plate, but come to get it upon the bench it was a little tight; or if a cutter, in hardening the hole which at first was right, now is a little out of round; perhaps he has left it small and ground it out in the universal grinder, and, as with the lathe job, it wants "just a hair" taken out of it. The lathe job cannot be chucked again or the cutter go back into the grinder. We speak of these cases merely as examples, and not as embracing, even in a small measure, the uses for laps in the shop. Workmen accustomed to using them know their value and the many occasions upon which they can be used to advantage.

Our shopmate looks at our row of laps and says, "Say, Joe, got a $1\frac{1}{8}$-inch lap? This thing is just a shade small."

We pick out a $1\frac{1}{8}$-inch lap, push a mandrel into it, and hand it to him. A great change comes over our friend's face. He smiles now. "Oh," he says, "that'll just do it." He knows how to do the rest, and in a few moments is back again with the lap and mandrel, and very well disposed toward us both — the lap and myself.

Now, if there is no set of laps, you will see him down upon the floor, pawing over a box at the end of somebody's lathe, or under the bench, rattling around among a miscellaneous collection of chunks of cast iron, brass, copper, lead, etc. The gloomy look gets gloomier, and he talks rather forcibly about there being everything there but what he wants. He has finally to take something larger and turn it down.

When it will just enter the piece he wishes to lap, he files it a little on the end, puts on some oil, and scatters a lot of emery all over the lathe, so as to be sure and get some on the lap, and tries to crowd his cutter, or whatever it may be, on. Of course it sticks and gets hot, and so does he. More oil and emery, and by and by it slips onto the place he has turned upon the lap; but there was rather more to come out than he reckoned for, and if he is in luck he will have room to turn another spot for a lap; if too short, then he must hunt another chunk. This form of lap is what we call the solid-chunk lap, and is one of the meanest we know of.

We have seen them made of wood and sawed in the end for three or four inches of their length, with a wedge in the saw slit at the end for adjustment. This makes a lap some like a policeman's club — biggest at one end. Those who have tried this form will appreciate the beauty of this method of adjustment.

The idea seems to be quite generally entertained that a lapped hole must be right; but the fact that a hole is lapped is no guarantee of its perfection.

The "S. C." lap is made of almost anything that comes handy — cast iron, wrought iron, machine steel, brass, copper or wood, and if any one of them in this form of lap will make a straight hole, it is news to us.

Lead Laps and Cast-Iron Laps

Then there are lead laps, and, in fact, many think laps must be made of lead. This type is more generally used in machine

shops. In speaking of laps many understand you to mean lead ones, as though there were no others. They have been used for years in gun barrels and nothing better seems to have been found, but for a set of laps for a machine shop to be arranged in sizes to conform to the reamers and mandrels in use we are decidedly of the opinion that soft cast iron is the best material to use.

We do not wish to be understood as saying that good holes or spindles cannot be made by lead, as it is used in some forms of laps to good advantage, but we think for the use we have in mind cast iron is better.

First, perhaps it will be well to state some of the difficulties encountered in the use of lead laps and compare them with cast iron. Lead laps are made in several ways. The most common, probably, is to cast them into a mold around a taper mandrel with a groove running its entire length, into which the lead flows and prevents the lap slipping. The mandrel is put into an iron or wood mold usually made in halves. At each end for a short distance the mold fits the mandrel or is made to by inserting a narrow ring. This holds the mandrel central in the mold and retains the lead. When the lead is cool the mold is opened and the lap turned to size on the mandrel.

Among the faults which have been found with lead laps for lapping holes is their liability to lose their form. Experience has taught that a lap will produce better results if it is kept as near to an even diameter its entire length as possible. Good results cannot be gotten from laps that are "off" in this respect. They should be kept as near straight while using as possible, by reversing the piece to be lapped on inside work, and by reversing the lap on outside work as often as convenient, and if the lap is still uneven it should be made right by turning, grinding or filing. We have found it much harder to keep a lead lap of even diameter than a cast-iron one, and for these reasons we slit a cast-iron lap and usually a lead one. When the lead lap is enlarged by forcing the taper mandrel through it, there are times when it does not respond to a light tap and is given one a little harder. It takes some more force to start a mandrel on a lap than it does to keep it going, as in most cases with things that move, and the mandrel sometimes goes too far; then it has to be driven back and perhaps out, the lap shut up and the mandrel again adjusted or the lap reduced by filing or turning. A cast-iron lap has sufficient elasticity to close on the mandrel when it is forced back, and that is all that it is necessary to do to reduce the size of the lap.

Lead laps enlarge most, as the taper mandrel is forced into them to increase the diameter at the back end where the mandrel is largest and the lap consequently thinnest. This fault is not nearly so apparent in cast-iron laps.

To insure, as far as possible, the even enlargement of laps, either cast-iron or lead, the mandrel should fit the lap its entire length. If it does not, it will stretch the lap most at the places where it fits.

After the lap is fitted to the hole to be lapped the addition of the cutting material — usually emery — as it imbeds itself in the lap will enlarge it enough to cause it to cut as much as it should, and as it enlarges the hole the lap is removed, wiped and adjusted again. Laps quite often are run too fast. Better results can be obtained at a moderate speed; the work does not get so warm, and it is thought that the laps cut faster; the emery stays upon the laps better and does not fly off. A lead lap must usually be held in the hand while the mandrel is being rapped through it. If it rests upon its end upon a block while being rapped it is apt to swell or get pinched at that end. A cast-iron one can be rested in this way without injury or can be put in a mandrel press and adjusted in that way.

Equipment for Making Laps

The tools necessary for lead laps usually are a ladle, some molds and taper mandrels. Iron molds are all right, but wooden ones used by some soon char out and become useless. For a set of cast-iron laps a few tools are necessary. They are not very expensive and when once made seldom or never have to be replaced.

Six taper mandrels, Fig. 47, reamers and reamer drills are all that are actually necessary for a set of laps to be used in connection with the usual sizes of reamers and mandrels from ¼ inch to 3 inches diameter. Some additional rigs that have been made from time to time, and that have been found convenient in lapping generally, will be spoken of later.

A handy form in which to have cast iron for hole laps is in round pieces of different diameters, 18 or 20 inches long. The laps can be cut from them, chucked, drilled and reamed.

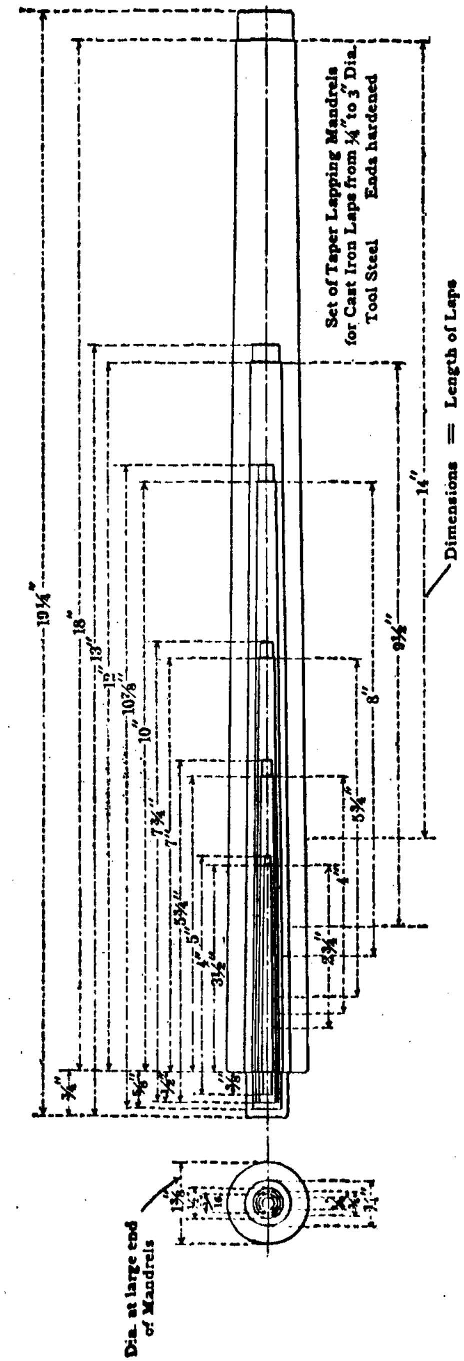

Fig. 47. — Taper Mandrels for Lead Laps.

From $\frac{1}{4}$-inch to $\frac{1}{2}$-inch diameter we use copper or brass; from $\frac{1}{2}$-inch up, cast iron. We make the laps for holes as long as we can conveniently make the taper reamer. Fig. 47 shows a set of taper mandrels for laps from $\frac{1}{4}$-inch to 3 inches diameter. The smallest takes laps of $\frac{1}{4}$ and $\frac{5}{16}$ inch diameter, and the others in regular order, $\frac{3}{8}$ to $\frac{9}{16}$, $\frac{9}{16}$ to $1\frac{3}{8}$, $1\frac{3}{8}$ to $1\frac{5}{8}$, $1\frac{5}{8}$ to 2, 2 to 3 inches. This number (six) is probably the smallest that should be used, and two or three more would be better.

Taper Reamers for Laps

In connection with taper reamers for laps, perhaps it may be well to speak of the difficulties in making them. They are necessarily long and slim, and difficult to harden without springing, and although to men accustomed to making them there may be nothing new in what follows, it may be of some assistance to those who are not familiar with the work. In addition to careful heating and cooling, the reamers can be straightened after tempering even if they are quite badly sprung. Cool them first in cold water and then in lard oil, leaving them in the water an instant until the red disappears; then finish cooling in oil; this leaves a softer core of metal in the reamer and the latter is more easily straightened. Turn up an emery wheel to fit the flutes and grind them out; this smooths the front face of the tooth, and gives it a much keener edge when the top is ground. After drawing the reamer may be placed in the lathe on an old pair of centers shaped up and hardened and kept for such jobs, with a piece of hard wood in the tool post. Warm up the reamer with an alcohol lamp or Bunsen burner as hot as possible without starting the color; bring the wood against the high side of the reamer with the cross feed screw, and spring the reamer until it is true enough to grind. The operation will have to be repeated a few times, trying the reamer as one would a shaft, by revolving it with the hand, on the centers, after springing it. The reamer can be ground in the universal grinder, round, as with a taper plug, stoning a clearance by hand afterwards. Previous to this last grinding, the flutes should be again polished out. The first grinding in the flutes is to smooth any roughness left in milling and brighten the surface sufficiently to color in drawing. The second time more attention is paid to smoothing up the face of the tooth

for an edge. The taper mandrels are made of tool steel, with the ends hardened previous to taking the finishing cut in the ordinary manner.

The drills are long twist drills, and if they cannot be cut in the shop, an ordinary drill may be spliced by turning a short shoulder on its shank and fitting it into a piece long enough for the lap, then soldering it in.

Chuck for Holding Mandrel and Lap

Figure 48 shows a handy chuck for holding the mandrel and lap. Make several sizes of bushings to go with the chuck, with

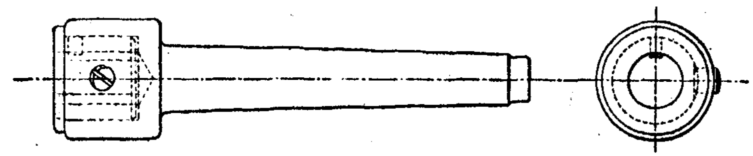

Fig. 48. — Chuck for Mandrel and Lap.

different sized holes in them to fit the different mandrels, one chuck in this way answering for all sizes of mandrels. A screw or pin goes through the bush, whose point just clears the flat spot

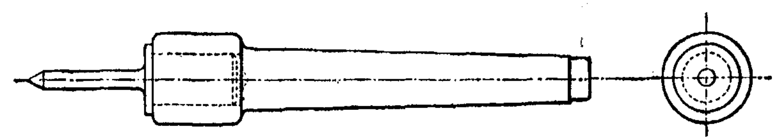

Fig. 49. — Center Held in Taper Shank Collet.

on the end of the mandrel, preventing it from turning in the bushing. The mandrel and lap can be taken out by simply drawing back the tailstock spindle and pulling the mandrel from the chuck. A center held in a taper shank collet, as shown in Fig. 49, in the tailstock is handy for inside or outside lapping. It is long enough in one case to run the piece being lapped off upon it, to remove the lap from the lathe, and in the other the lap can be run off upon it to remove the piece from the lathe.

From the emery and oil that works into the center at this end of the mandrel, the center wears considerably, and this is a handy form to repoint and lasts a long time, also it is easier to make than the common center. Two or three sizes can be used to

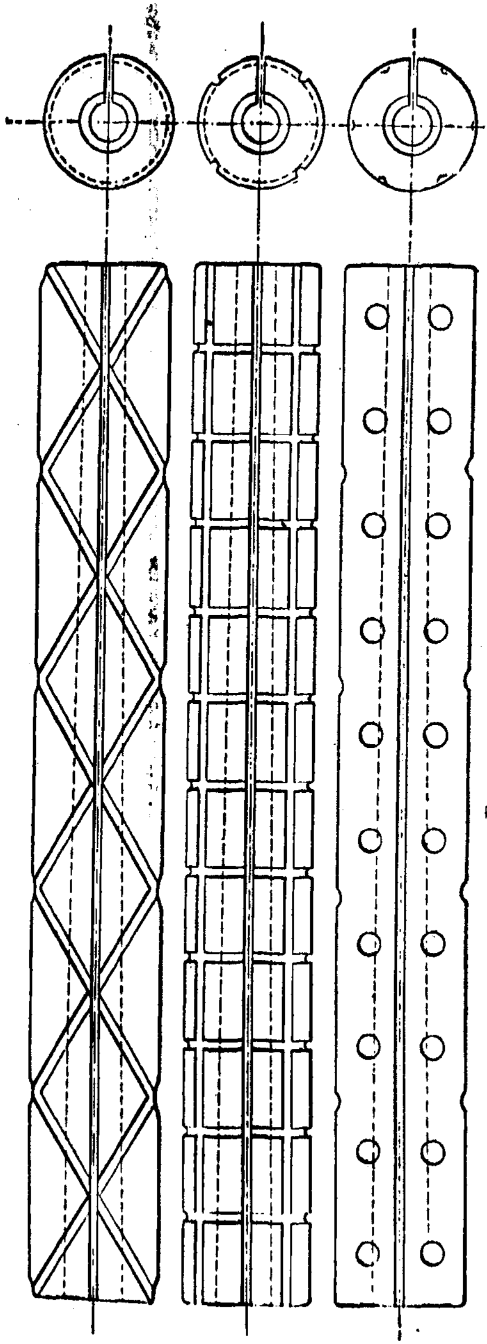

FIG. 50. — Ways of Scoring Laps.

advantage. With the tools shown, cast-iron laps can be made by any boy who has survived two years in a machine shop, with the usual attention from the foreman.

Scoring Laps

Figure 50 shows three ways of scoring laps. The spiral can be done in the milling machine, or it can be done well enough with a drill file in the vise. The straight form can be made in the lathe entirely, or the lengthwise scores can be cut in the miller. The drill-spotted lap is center-punched, and then spotted at the drill press in a V-block going down just to the corner of the lip of the drill. Either of these forms works well, and can be used as found expedient. Laps of ½ inch and under need not be scored. A key or feather is not needed in the mandrel, as the

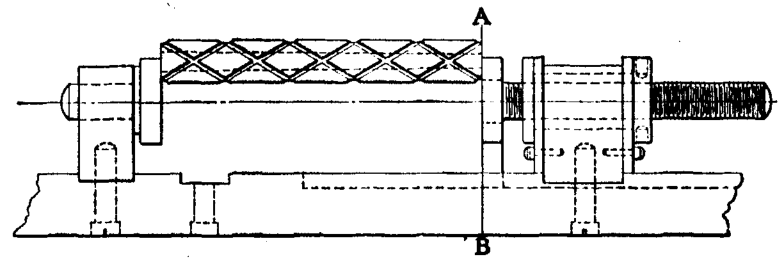

FIG. 51. — Lap Holder for Milling Vise.

laps never turn, except perhaps in cases of laps of small diameter that are quite thin. A satisfactory taper for reamers and mandrels is ½ inch per foot.

Set of Laps for Holes

In many cases a set of laps for holes might be all that was needed, and very likely would soon prove their value. The laps are not very convenient to hold while slitting them with the ordinary means. Some hold them on the bed of the milling machine with two straps having a round nose forged at one end to enter the hole in the lap, resting the lap in the T-slot of the bed or in a V-block. Fig. 51 shows a holder that will take any lap and can be placed in the milling vise. The work will not cramp the cutter held in this way by its ends. If the laps are slit on the mandrel the machine must be set to the taper of the mandrel, and if one cuts through the lap he marks the mandrel. It is an easy rig to make and set.

Mandrel Press for Laps

If the laps are enlarged by rapping the mandrels into them, a block like Fig. 52, for the end of the lap to rest on while rapping, is handy, or a mandrel press like Fig. 53, which can be held by its lower jaw in the vise in an upright position, or by one of the side bars in a horizontal position — or in still another way by fasten-

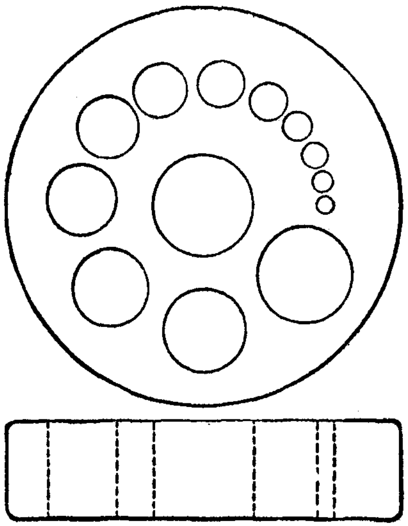

Fig. 52. — Block for Resting End of Lap.

ing a plank upon the bench so it will project enough beyond to allow the side bars to drop through two holes cut in the plank.

Figure 53 shows the construction of this press. The necked side bars are $1\frac{1}{2}$ inches square, of machine steel left rough, centered and nicked in. The right-hand one has the corners turned off slightly to allow the anvil shown in section to turn on it. It is held in place by the hickory wedge shown at *a*.

The follower is made of sheet steel — the sides about $\frac{3}{32}$ inch thick and the connecting piece $\frac{1}{8}$ of an inch thick. That portion of the sides above and below the saw slits is bent at a little sharper angle than a right angle to grip the side bars a little, causing

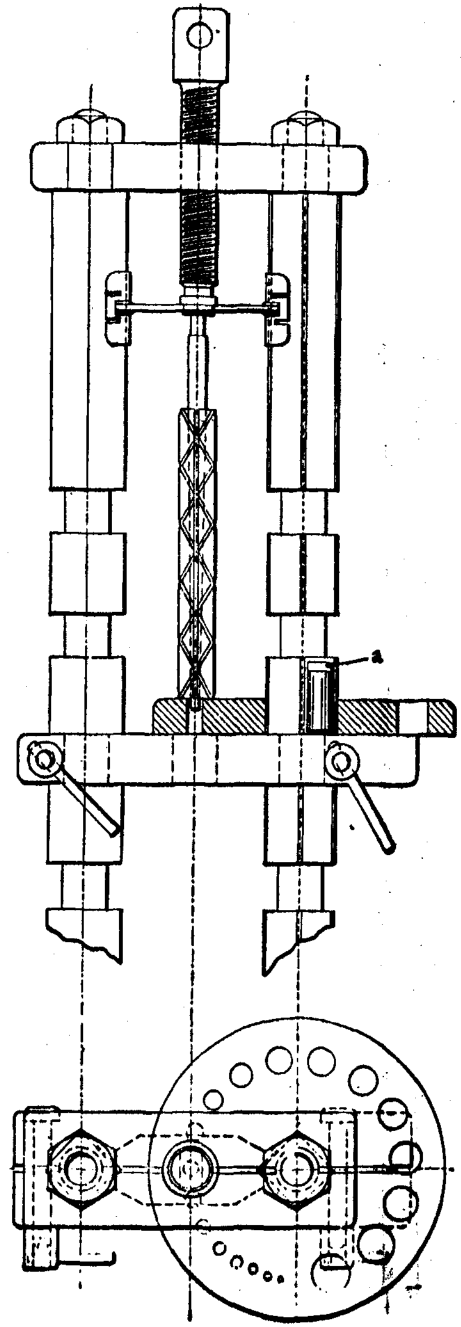

Fig. 53. — Mandrel Press for Laps.

sufficient friction to hold the piece wherever it is moved. The ends of the pieces should also be turned out a little so the edges will not catch upon the side bars when moved up or down them. A screw is preferred to a rack, as it is easier to get a very slight movement of the mandrel when it is needed.

Forms of Laps for Outside Work

Figure 54 shows different forms of laps for outside work. Lead in this form of lap does very well, as it is protected by the casting into which it is poured, but even here cast iron may do just as well. No. 1, Fig. 54, shows a lap casting recessed and filled with lead. The retaining lips in the casting are dovetailed a little to hold the lead, and a few holes are drilled in the casting for the same purpose. The lead is run in at the bell-mouth hole at the top. By making the recessing in this form of lap shallower, sheet brass, copper or lead can be forced into it for laps over 1 inch diameter. The sheet metal can be curved some, as it is bent so it will spread out into the dovetail when forced in. A piece of round stock some smaller than the size to be lapped can be used to force them in place. Get the sheet metal wrapped in place as well as possible, then by putting the round piece in the lap and the whole between the jaws of a vise the sheet metal can be forced into place. Copper, or brass, should be annealed before putting it into the lap, which may need a little touching up with a scraper or file to bring it to a good bearing on the work to be lapped, after the lapping pieces are in place. In connection with the outside laps it may be well to mention a use for them not generally understood — their use upon reamers. One form of reamer has been used quite largely and very successfully.

Laps Used upon Reamers

The flutes were milled sharp — without land. The reamers were hardened, the flutes ground out and then the reamers were ground in the universal grinder cylindrical — just as straight work would be, and left about .002 over size, to which they were reduced by lapping with a lap shown in No. 2, Fig. 54. This lap is adjustable and the slit is at such an angle that the teeth of the reamer running backwards do not fall into it. A piece of wood

is sometimes put in the slit if the reamer runs at all rough, but this is hardly ever necessary. The reamer comes down to size quite rapidly in lapping, as the surface to be lapped is quite limited. Cutting the reamer sharp with no lands on the teeth, after grinding in the universal, leaves just about enough land, although this can be regulated if too much stock has been left in diameter by grinding with an emery wheel on the front face of the teeth and cutting the lands down as much as desired. All reamer makers pay particular attention to this face of the reamer tooth, and very many machinists making reamers in the shop pay none at all to it, except, perhaps, to stone it a little.

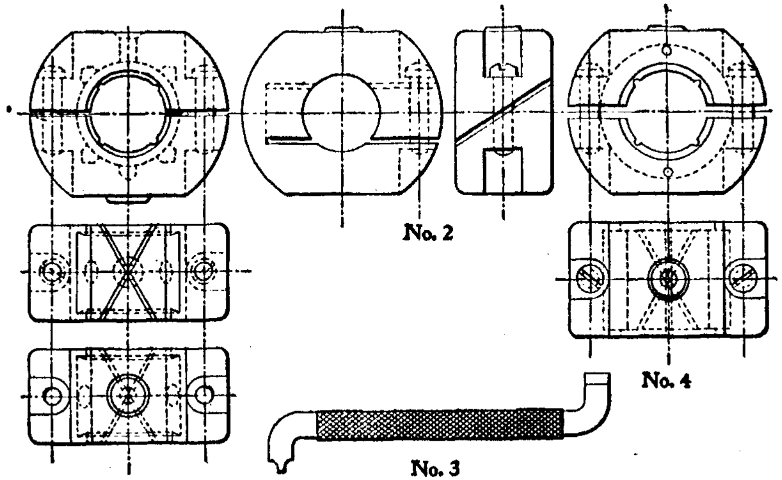

Fig. 54. — Different Forms of Laps for Outside Work.

Material for Outside Laps

For sizes of outside laps up to 1-inch diameter flat bars of cast iron from 18 to 24 inches long, of proper widths and thickness, can be used. They are cleaned up all over on the planer and cut off as needed. For larger sized castings of the form shown at No. 1, Fig. 54, the casting is in one piece, a hole cored in it. The screw holes for the adjustment are drilled and tapped, it is then placed on a face plate, the hole bored and sawed in halves in the milling machine. The boss on one side is for marking the size, and is high enough to allow for two or three removals as the laps wear and are rebored to other sizes. There is not finish on them, the spots where the screw heads rest being swept off with a counter bore.

Lapping Screws and Nuts

These forms of outside and inside laps are useful to lap screws and nuts. A nut, sometimes, made for a gage when hardened will close up a little, and can be lapped to size in a few minutes by cutting the proper thread upon an inside lap. A screw can be treated in the same way. Long screws, if they show some slight unevenness that causes the nut to run hard or bind, can be reduced very easily by lapping and made to run uniformly. The halves of the lap must be kept parallel by the adjustment screws, or the lap will come on the thread and bind. In fact, for either screws or straight-wound work, it is well to be careful in this respect. It is easy to do this by watching the openings between the halves of the lap, and keeping it cf a uniform width with the adjusting screws. For adjusting these screws use a screw-driver, shown at No. 3, Fig. 54.

Frequently for screws over $\frac{3}{4}$-inch diameter is used a recessed lap, placing the screw in it and pouring lead around it.

Lapping Duplicate Work

For lapping a large number of pieces of the same size, laps made as shown at No. 4, Fig. 54, are a good form. The lapping pieces are simply rings of metal, and can be replaced at small expense. A pin, shown in each half of the lap, holds the lapping pieces in place.

The length of outside laps must vary some, according to the length of the work upon which they are to be used; but for an average length, a lap of $\frac{3}{8}$-inch diameter would be $\frac{5}{8}$ inch long, $1\frac{1}{2}$ inches diameter $1\frac{1}{2}$ inches long, a 3-inch lap $2\frac{1}{2}$ inches long. If the set could contain two or three cf the same size, there should be one of each size about twice these lengths. We seldom use emery coarser than 120, and almost always flour. There is considerable difference in the grades of flour by different makers. For finish lapping use washed emery, and if this cannot be obtained, stir up the flour in the oil, and, after allowing it to settle some, use the top. This is rather uncertain business, as

one is apt to get a few particles of the coarser emery in it, and i is exasperating, after getting a plug finished, to have one of thes rocks come swimming along and plow out a canal the lengtl of the plug. For very close and particular work, roughing an finishing laps are used; but generally by washing the lap thor oughly in benzine, one lap can be made to answer.

The tools for making these laps and the laps themselve should be kept on racks similar to those used for reamers an mandrels and convenient to them. A set of laps, that can b got at and used us easily as the shop mandrels and reamers are seems to be a very good feature.

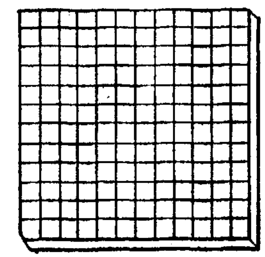

Fig. 55. — Flat Cast Iron Lapping Plate.

Preparation of Emery for Use in Lapping

To prepare emery for lapping, accurate tools, gages, punche dies, etc., fill a half-pint bottle with machine oil and emery of th proper number suitable for the work in hand; the proportions c about 7 parts of oil to 1 part of emery by bulk is right. Mi thoroughly and allow to stand for a half-hour, during which tim the heavier particles of emery will settle to the bottom. No take the bottle and carefully pour off about one-half the content without disturbing the settlings. The portions poured off cor tains only the finest emery and will never scratch the work.

Applying Emery for Surface Lapping

For surface lapping put some flour emery in a linen bag an tie up closely with a string. Dust out the emery by striking th bag against the surface plate; use turpentine for rough lappin and the dry surface plate for finishing.

Lapping Plate, for Keyseat Gages, and Flat Gages

The lap shown in Fig. 55 was a plate of cast iron which was first scraped to a smooth finished surface, after which parallel grooves, $\frac{1}{16}$ inch wide by $\frac{1}{32}$ inch deep, were cut upon the surface, forming small divisions $\frac{1}{4}$ inch square. This plate was charged with fine emery and turpentine, and when used on keyseat gages or other flat pieces was capable of producing a very fine surface.

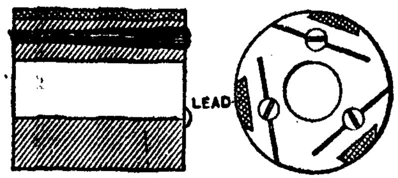

Fig. 56. — Wooden-bodied Lap.

Wooden-bodied Lap for Milling Cutters

Figure 56 shows a lap formed of a smooth turned piece of hard wood, on to each end of which was fitted a ferrule of wrought iron to prevent splitting. A narrow slot was sawed through the center and into this was driven a wooden wedge to compensate for wear. One of these laps would last for a long time and they were used in milling cutters when the amount of stock to be removed from the holes was not sufficient to warrant the use of the grinder. For removing tight spots, etc., this lap is very valuable.

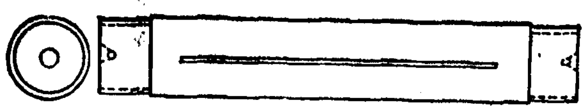

Fig. 57. — Arbor-lap for Ring Gages.

Arbor-lap for Ring Gages

The lap shown in Fig. 57 is a cast-iron cylinder that was bored to fit the arbor with which it was to be used. Three strips of lead were dovetailed across the surface and these carried the charge of emery and turpentine oil. Three small tapered holes were drilled and reamed longitudinally, and tapped at the small end to receive the taper expanding screws. After these were fitted, diagonal slots, which intersected the holes, were cut, so that by a

slight turn of the taper screws the lap could be expanded to adjust it for wear. This lap was used on the inside of ring gages.

Contracting Lap for Plug Gages

For lapping the outside of plug gages the lap shown in Fig. 58 should be used. It consists of a casting bored out to the required size and fitted with three wide strips of lead. A slot cut through the lugs on the upper side and fitted with a pair of set screws was used to form the means of adjustment. A handle was provided to prevent the lap from turning while the plug gage upon which it was being used was revolved in the machine.

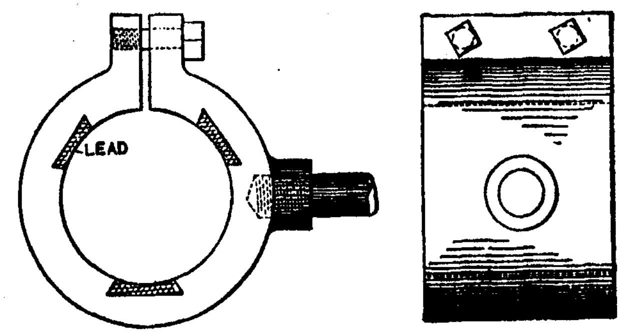

Fig. 58. — Contracting Lap for Plug Gages.

Lap for Worn Micrometer Faces

To lap a pair of micrometers, the faces of which have become considerably worn, procure a small piece of plate glass and place a few drops of oil and flour of emery upon one side; leave the other side of the glass perfectly clean. Then close the micrometers tightly upon the glass, and slide the glass back and forth between the jaws for some time. Then after thoroughly cleaning the first jaw, the glass should be reversed and the process repeated upon the other jaw. In a short time the micrometers, so far as the jaws are concerned, will be as good as new.

Lapping Machine for Thread Gages

The lapping of plug and ring gages is the most important part of the construction of such tools. A screw plug or ring gage should never be case-hardened; even if it is made of machinery steel and drawn to a blue, it is so brittle that the top of the thread breaks off; even when fitting in lapping it has been known to break off. Lapping is very slow and tedious work when using an engine lathe, by moving the shifter to and fro; for that reason for lapping small thread gages a lapping machine was constructed as shown in Fig. 59. The spindle extends about 5 inches with a left-hand screw *a* on the end. A cross-bar *b* is fastened to the end of the machine with two screws *c c*, two ½-inch holes are drilled through the ends of the cross-bar to fit the two studs *d d* and these are held in position with nuts *e e*. A slot is milled in the end of each stud to fit the lever, and the latter is held at the end with a pin and attached loosely to a half-

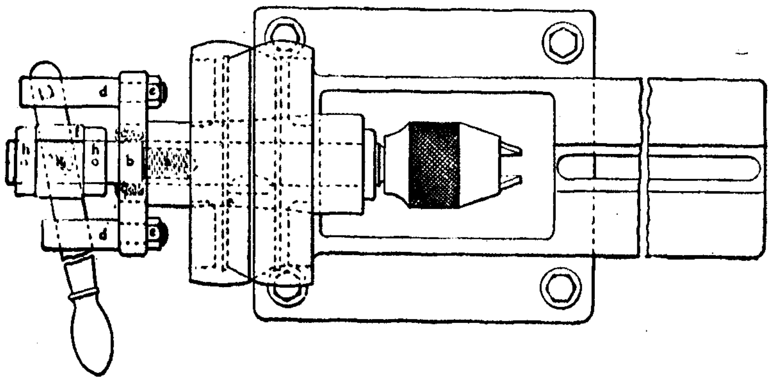

Fig. 59. — Lapping Machine for Plug and Ring Gages.

round box *f* by a screw *g*, the box being mounted freely between collars *h h*. By moving the handle to and fro the spindle is driven right and left. A large drill chuck is used to hold the laps and screw plugs when lapping. With this machine the operator is in a sitting position, with his left arm on the lever and the right hand on his work.

Lapping Gages and the Use of Test Gages for Them

The first thing in lapping is to get the emery in good condition. Test gages are used in lapping the ring gages, and a tap size plug is shown in Fig. 60. Right here is a little kink: To lap a plug round and straight, after it is ground never lap it across the sur-

face slowly, but draw the lap back and forth an inch to a turn, as indicated by the lines on the plug; by so doing a perfectly straight and round surface is obtained. It will be found that a good many plugs are out of round because the lap has been drawn across the surface too slowly. When within .0001 inch of size, the lap and plug should be cleaned to remove all the emery and only machinery oil used; this will be found to give a very brilliant and shining surface. Another test plug used is shown in Fig. 61. This has only four threads, with a sharp V-bottom, and measures

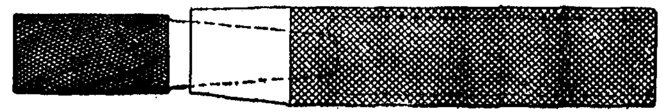

Fig. 60. — Tap Size Plug Lap.

.001 under size on the top or outside diameter, but must be exactly to size measured in the angle of the threads. Still another screw plug is used, with a V-bottom thread, and to measure the right size on top, but .001 under size in the thread angle. Then a screw plug is used that is standard almost everywhere, and should be double the width of the ring gage. By having these test plugs an accurate external thread gage can be made; without them one cannot know where to lap when the gage doesn't come right.

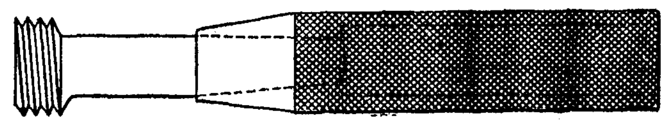

Fig. 61. — Test Plug.

Overcoming Effects of Overlapping

If the ring gage happens to be lapped a trifle over the size, a very practical way to save it is to heat the gage to a light straw color and let it cool slowly; it will then have shrunk sufficiently to allow the straw coating to be lapped off, and sometimes more, saving the gage, providing the lead is right. Sperm oil should be used when fitting thread gages, and not thick, heavy oil, as that is likely to cause false fitting. It has been found when a screw plug and ring fit fairly well in a horizontal position, that if raised to a perpendicular position they will fit much easier, because the weight of the handle prevents true fitting in a horizontal position.

Sets of Ring-thread Gage Laps: Their Use

When lapping ring-thread gages sets of five laps of machine steel should be used to assure a perfect lead, and these should be cut with the chaser, with .0001 inch difference in the diameters. There should be one straight lap for the top size and one lap with V-bottom, .001 under on top of the thread, but right to size measured in the thread angles; if it is found that the top of the thread in the ring gage is to be lapped, this lap will do it.

Adjustable Lap-holder

An adjustable lap-holder, shown in Fig. 62, is useful. It is made of tool steel, is spring tempered, and has a very thin slot in

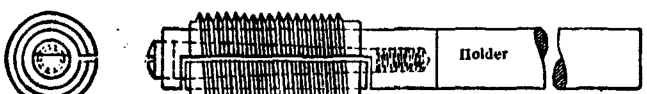

Fig. 62. — Adjustable Lap-holder.

the center and one at each end of the lap cut to the center line. A taper screw in the center gives it a very fine adjustment and obviates hammering on the end of the lap, which upsets the end and sometimes changes the lead of the ring gage.

Stock Allowances for Lapping

A screw plug can be measured all over with the micrometer and wires so that no test gages are required. In hardening such a plug it generally swells from .0002 to .0007 according to the size of the plug, and it will be found that the extreme end swells from .0001 to .0003 more; so when cutting a screw plug .0003 is enough to allow for lapping. But in the ring gage .001 inch should be left for lapping, as both ends open and the center shrinks.

Laps for Screw Plates

Screw plug laps are made in a similar manner to the ring gage laps. Taps are made, one with V-top and flat bottom and to

measure right on the thread sides of the angle, and one tap with "V" or sharp bottom and top, and to measure .0001 under the angle. Five laps are used with a difference of .0002 in diameters. For the top of the threads on the plug a straight lap is used to bring to finish size.

A lap-holder is shown in Fig. 63. This is made of machinery steel nurled on the outside and bored to receive the lap rather freely. Cone-pointed screws hold the lap in place. When lapping large plugs, a short piece of wire screwed into the holder acts as a handle and is found very convenient.

When only the bottom of the thread on the plug is to be lapped, a single thread lap will do the business. This is made of soft

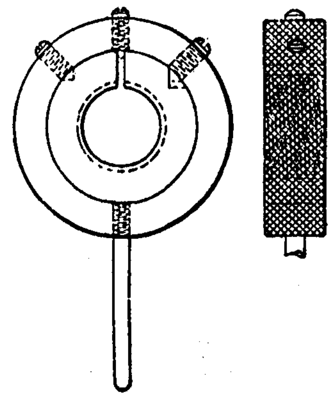

Fig. 63. — Lap for Screw Plates.

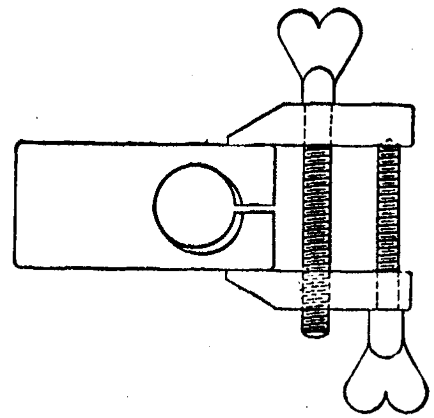

Fig. 64. — Lap for Screw Plates.

metal, the width of thickness of the thread to be lapped, and tapped out the same as an ordinary lap. The sides are scraped off for clearance, and a slot is cut in the front end. The lap is held and adjusted with a light clamp like Fig. 64. This has proved very convenient, as it does not affect the lead, angle or the top of the thread.

Lapping and Brazing Black Diamond Tools

Figure 65 shows a fixture for lapping black diamonds which are used in the forms shown at *B*, and *C*, Fig. 66, for finishing pieces made of brass and vulcanized rubber. The shank of the holder *D* revolves freely in the body *E* for lapping round-nose diamonds, and the nurled nut *F* clamps it in position for lapping those of angular shapes. The splined collar *G* is graduated in degrees for setting the holder at the required angle. The adjustment for the required degree of clearance is obtained with the nurled and pointed screws *H*. The points of these screws hold the fixture in position on the wooden top of the rotary lapping machine. As will be seen in the illustration, the fixture can be

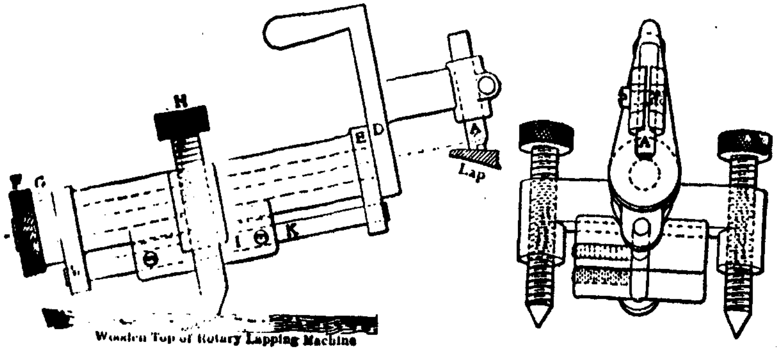

FIG. 65. — Fixture for Lapping Black Diamonds.

adjusted to bring the axis of the holder to lie at various angles with the top of the lap, so that when a round-nose diamond is lapped by rocking the small handle back and forth the shape of the clearance will be a section of a cone. *I* is a movable weight attached and sliding on the rod *K* for applying pressure to suit

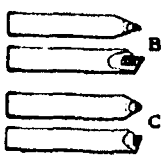

FIG. 66. Black Diamonds.

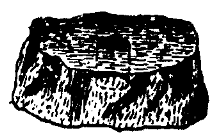

FIG. 67. — Crucible for Brazing Diamonds.

the various sizes and shapes of diamonds. Fig. 67 shows a crucible for brazing the diamonds into the bessemer steel shanks. It is made from a remnant of a wornout crucible as used in brass foundries. A hole a trifle larger than the shank is drilled into it, into which brass filings and borax, and the shank containing the diamond, are placed. It is then put into the fire in a forge and heated until the brazing is completed.

Splitting a Diamond

Figure 68 illustrates a method employed with success for breaking a large valuable diamond at a given point. The diamond was of an oval shape, about $\frac{3}{8}$ inch long, $\frac{5}{16}$ inch wide, and $\frac{1}{8}$ inch thick. The firm wishing to purchase this diamond informed the dealer that they would use it provided he would deliver it in two parts, cleaving it in the center so that each piece would be $\frac{5}{16}$ inch long, and $\frac{5}{16}$ inch wide. The dealer then informed them that the cleaving would increase the price of it considerably, because it would have to be cut with a thin disk the edge of which would be charged with diamond dust, a slow and costly operation. The dealer was then informed that one of the firm's men would undertake to part the diamond at a given point in a short time, and he at once consented to have him try it, saying that he was willing to learn, because he never saw a diamond of that shape parted successfully without cutting. A piece of

FIG. 68. — Breaking a Large Diamond.

bessemer rod $\frac{3}{8}$ inch diameter, and $1\frac{1}{2}$ inches long was secured, and an oblong hole was drilled and filed in it to receive the diamond, and after brazing it in, notches were filed a measured distance from one of the ends. After reaching the diamond from all sides and giving it the breaking strain, surprise was experienced in feeling it break more nearly like a piece of slag than like glass as was expected, but the break, nevertheless, was straight and clean, and at the given point.

Diamond Dust for Laps and Sapphires for Cutting Tools

The two above-named precious stones are extensively used in the making of small tools of precision, and as their use in connection with methods for accomplishing work is not widely known, a little information along this particular line will be of value and interest.

The use of the diamond in mechanical work is more extensive. The toolroom that does not possess a little black diamond for dressing its emery wheels is a poor one indeed. But this cannot be said about the majority of toolrooms which do not keep the diamond in pulverized form, because often their class of work does not warrant it; but we have known of places where, if such an article had been at hand, it would have facilitated matters very much, and paid for itself twofold both in manipulation and results, on certain jobs.

This diamond dust comes in small vials and is classified by numbers, No. 1 being coarse, and as the numbers proceed the dust becomes finer. It is essential to assign certain numbers to cer-

FIG. 69. — Diamond-charged Lap.

tain classes of work, just as different grades of emery are assigned to different classes of work. Watch-tool work demands the use of this diamond dust, although there are many other classes of work on which it is extensively used.

For grinding out very small holes which may range from .025 to .250 in diameter, the diamond-charged lap in connection with a traverse grinder on a bench lathe cannot be equaled. A lap of this kind is entirely different from an emery lap, as will be seen from Fig. 69. It is made of mild steel and has a taper shank

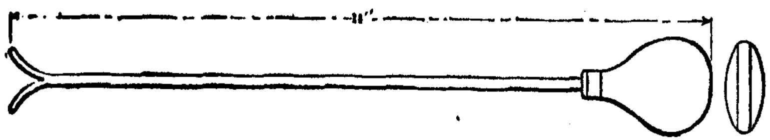

FIG. 70. — A "Harker."

which fits into the spindle of the traverse grinder. Soft metal for such a lap is desirable for the reason that it can be charged far more easily than if it were hard. The part of the lap which is to be charged is marked *A*. This charging is readily done by taking two pieces of steel which have been hardened very hard, surface one side of each piece, then holding one piece in the vise with its surfaced side up and placing thereon a little diamond dust which has previously been mixed with a drop of good oil, roll the lap between these two hardened pieces of steel and the diamond will be forced into the lap. A lap of this description does

its own grinding the same as an internal emery wheel, just grinding that part of the hole which runs eccentric, not following the hole the same as an ordinary emery lap does.

One of the most important items to be observed when doing this grinding is not to force matters, especially if the lap is of a very small diameter, as it will tend to follow irregularities of the hole and the result will be unsatisfactory. The lap should just hit the high spots in the hole and gradually grind them off. By placing a screw-driver or some such tool against the grinder's foremost bearing, at the same time holding the handle against one's ear, the sound when the lap first comes in contact with the work can be readily detected.

A more suitable tool for this purpose is shown in Fig. 70, it being termed a "harker"; it is nothing more than a piece of No. 30 drill rod inserted into a little piece of wood which is finished off to a suitable shape to hold against one's ear, the other end of the rod being split and spread fork shape so that it can be rested against the spindle or frame of the grinder. When grinding, if a lap is kept well lubricated with kerosene oil it will cut much freer and faster.

Handling Diamond Charged Laps

When doing this class of work it often happens that one must handle it entirely different from a larger piece. For instance, a piece of work 2 inches in diameter has a hole .040 in diameter; both must be accurately concentric with each other. Of course, if this were a larger hole it would be proper to grind the hole first and then place the piece on a true arbor and grind the outside, but this method would not be feasible in this case, as the arbor required would be too small. To accomplish work of this nature, a screw chuck may be made to fit the head of the bench lathe, as shown in Fig. 71; on this chuck is screwed a piece of brass which is a little larger than the diameter of the work to be held. Placing the chuck with the brass in position, bore out to a snug fit for the work (it should be understood that the work has been previously ground outside), then take a small alcohol lamp and hold it underneath the brass, warming it; this will allow the piece to be placed in position with ease. Remove the lamp and place a damp piece of cloth on the brass; this shrinks the brass and holds the piece securely and accurately. To release the work, heat the brass as before, and the piece may be readily slipped out and another piece put in, if there should be any more such pieces. Any one who has never tried this method may think it a slow way, but it would surprise him should he try it, as very little warmth is required to make brass expand enough for this purpose. If the

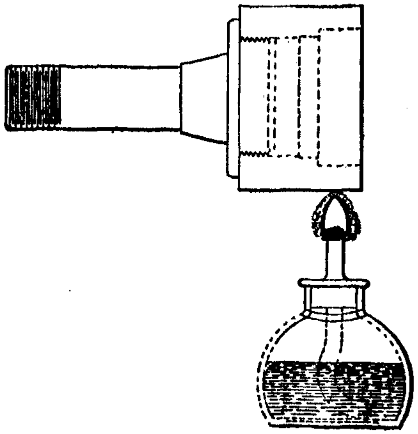

FIG. 71. — Screw Chuck for Accurate Grinding.

periphery of the piece that was being heated was out of round, then of course this method would not do. Some, accustomed to use either solder or beeswax, have found the above method superior both for accuracy and speed. Another style lap which

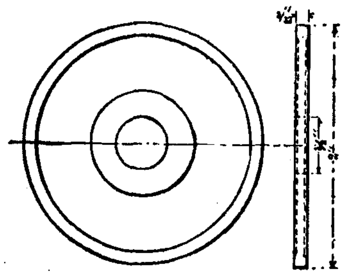

FIG. 72. — Another Style Lap.

it is quite extensively used is shown in Fig. 72; this is nothing more than a soft steel disk with its sides undercut. A lap of this kind is mostly used on a surface grinder for finishing out corners on small intricate tool work where an emery wheel would be useless.

Charging a Diamond Lap

For charging this lap the roller shown in Fig. 73 is utilized. This roller is made as hard as possible, and is held in a fork-shaped tool-post of the bench lathe. The lap is placed on an arbor which is held between the centers of the lathe. A little diamond dust mixed with oil is then distributed around the lap and the roller brought to bear against it; by revolving the lap the diamond is forced to imbed itself in the lap, repeating this until the lap is satisfactorily charged. The shaper also plays a prominent part in lapping out flat surfaces which are located in the side of a hole such as a die which has to be accurate as to size. The sketch, Fig. 74, show the construction of a shaper lapping device. The stud *a* takes the place of the tool-post; it is held in position by the threaded nut *n*. The forward part of *a* is milled out to form

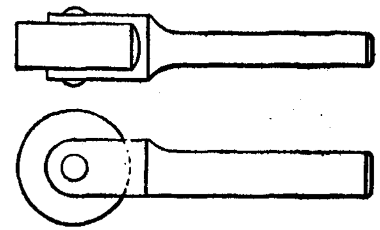

FIG. 73. — Roller for Charging Laps.

a tongue, on which fits the gray-iron lap *l*. A ¼-inch dowel which is a running fit in *a* lets *l* adjust itself in position. The length of lap is governed by its width and thickness, care being taken not to get the lap too long, as then it will spring and cause a convex surface. The screw *s* has a piece of drill rod through its head which allows it to be adjusted; while the machine is in motion it bears against a small disk, which in turn bears against a spring which puts pressure on the lap. Both sides of this lap may be charged, and for accomplishing this the roller shown in Fig. 73 is utilized, a handle being placed on the shank of the roller and the diamond distributed upon the lap; it is then rolled in with as much pressure as one can exert.

When the dimensions of the lap are large enough to allow a 10- or 12-inch stroke on the shaper to be had, then emery or carborundum is a very good substitute for diamond and is less expensive. Of course it will be noticed that it is essential to have the working face of the lap travel in a true plane with the ram of the shaper in order to insure accuracy.

The Sapphire as an Abrasive, Reamer, Forming Tool, Etc.

Leaving the diamond we now turn to the sapphire, which is another precious stone which is handled quite extensively on very small tool work; this stone has been made into reamers, forming tools, and applied to many different tools. Of course, as regards reamers, it may seem absurd, but when we consider that they were only .040 in diameter and $\frac{3}{16}$ inch long it may look more reasonable. These reamers were made square which gave the

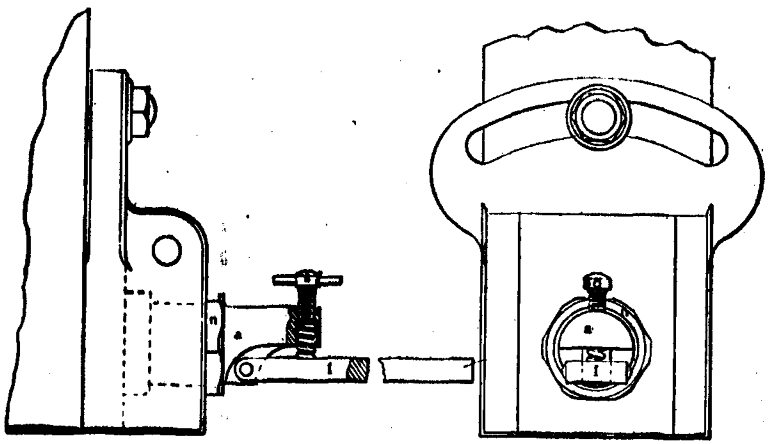

Fig. 74. — Lapping in the Shaper.

flutes, and also round with cutting teeth the same as a rosebit; they were used to finish out a hole which had to be accurate to size and in very tough phosphor bronze. The amount they had to ream out of each hole varied from .001 to .0015 inch. Steel reamers were used before these, but would lap under size in a few minutes. The sapphires stood up very nicely. They were ground up with the aid of a diamond-charged circular lap, this lap being the same as the one shown in Fig. 72, only smaller, it having a $\frac{1}{16}$-inch face and being $1\frac{1}{4}$ inch diameter. The reamer was held in a steel socket by means of jewelers' cement, which in turn was held, as shown in Fig. 75, in the taper shank by dowel *a*, it being allowed to float in position.

The sapphire forming tools which were of very small dimensions were held as shown in Fig. 76, these formers only acting as a sizer for a shoulder which had to be very accurate. The stock turned was soft steel and a steel tool preceded the sapphires. They were ground to shape in a surface grinder with the aid of a circular diamond-charged lap. Care must be taken when doing this kind of grinding to take a very small cut.

Sapphires have answered very well, on account of their hardness and smoothness, when set in the jaws of a special steady-rest which was used on a manufacturing job. One sapphire was set in the business end of each jaw, of which there were three; these were then lapped with the aid of a diamond lap to the true circle of the work which they were about to hold. For this special job they stood up remarkably well, being superior to anything that had been tried before.

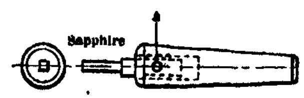

Fig. 75. — Taper Chuck for Sapphire Lap.

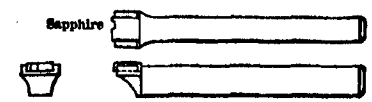

Fig. 76. — Holding Sapphire Forming Tools.

Rotary and Surface Laps: Their Manipulation

It seems strange that a great many mechanics have an idea that if a rotary or surface lap has a perfectly true flat surface most any one can produce absolutely true results. Such, however, is not the case. There are several facts to be kept in mind. It requires considerable skill, especially when lapping thin pieces, small straight-edges or long narrow strips; and it is possible and requires no skill at all to lap a piece convex or concave on a dead level lap 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 peen the work out of true. Furthermore, the outer surface of the rotary lap travels faster than the center and of course laps faster than the center, so it is obvious that the work should not be held in one position. The heating and peening of hardened pieces is not so liable to occur on surface laps as on rotary laps. It will be found also that the less the lap is used near the center the easier it will be to keep its surface straight. This is probably due to the speed being less near the center, which tends to roll and loosen the abrasive and therefore wears the surface more than where it keeps cutting.

With a great deal of practice, skill and good judgment both the rotary and surface laps can be kept in first-class condition; we have seen a lot of fine work done on laps and they did not have to be trued except at long intervals.

One rotary lap was made of an ordinary gray-iron disk mounted on a vertical shaft; it was faced and then provided with anchor holes or grooves. A coating of lead was then cast over the surface, and when cooled it was hammered to make it compact. Then it was faced up true, but not perfectly straight. It was left a little higher at the center, as it wears faster here on account of the speed being less; and by a little higher is meant two or three thousandths of an inch. It is provided with a pan all around, the edges of which project above the surface of the lap; a drip can for water is suspended above the center of the lap,

FIG. 77. — Lapping Block.

and when it is desired to lap a very thin piece without heating the water is allowed to drip freely.

Another handy device on this lap was a bar which was provided with ways, and a sliding head which traveled by hand from the outer edge to the center of the lap; it was fastened to projecting lugs at opposite sides of the lap frame and was also provided with means for adjusting the ways and the bar so as to stand perfectly square with the surface of the lap. The can could be easily removed when not in use. The sliding head had a square corner and an angle groove and was used for lapping the ends of round or square pieces. This lap was also tried charged with emery in cheese cloth and kerosene and gasolene, and it gave excellent results.

Rotary laps when not in motion may be charged by sprinkling abrasive over the surface and rubbing it in with a piece of round iron held in both hands. The surface lap mentioned above was used for finishing only, and was also a gray-iron platen covered with lead; it was charged the same as the rotary lap.

ADJUSTABLE LAPPING BLOCK FOR SNAP GAGES

A small and inexpensive tool is shown in Fig. 77. This no doubt is familiar to a good many, nevertheless it may be that its usefulness is not fully appreciated, so a few words in regard to it may not be out of place in this section. It was made for lapping snap gages, after these had been ground out to within .0005 inch of size, and Fig. 78 will give the reader a clear idea of the

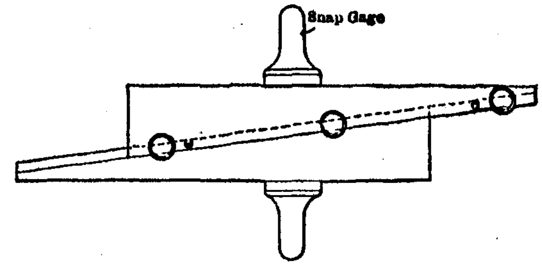

FIG. 78. — Lapping Block.

manner in which it was used. The body, which is made of cast iron, is composed of two pieces held together by a dovetail joint and gib. Two small screws serve to lock one sliding member of the body at any point along the other. To accomplish accurate lapping, the lap is first ground off so that both sides will be perfectly parallel, then each side is charged with flour of emery from a large bench lap. This adjustable lap is suitable for finishing snap gages ranging from $\frac{1}{4}$ to $1\frac{1}{2}$ inches in size.

MAKING AND LAPPING FLAT-END GAGES

The making of flat-end gages or end test bars is generally supposed to be a difficult job, and experience has taught that the

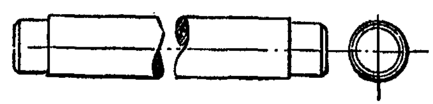

FIG. 79. — Flat-end Gage.

FIG. 80. — Flat-end Gage.

supposition is a correct one. Gages are of course made with varying degrees of accuracy, but we will take up the making of a test piece which is right and will stand the test in every way.

Most gages 3 inches or over in length are made like Figs. 79 and 80 because they are easier to make, the ends being turned a little smaller than the body, as shown, so that after hardening cat-heads may be fitted to the ends, and the body ground true and parallel, this making a cheap method of truing up and finishing. These round gages have a faculty of rolling away and getting lost, and for this reason we do not think they are as desirable as square ones, although the rig described will make them equally well.

To make a 1-inch standard test piece such as the Pratt & Whitney Company furnish, and which is shown in Fig. 80, a piece of tool steel of 110 points carbon is milled 11/32 inch square and to a length of about .01 over 1 inch, after which the corners are milled with a 45 degree cutter, leaving the end surfaces to be

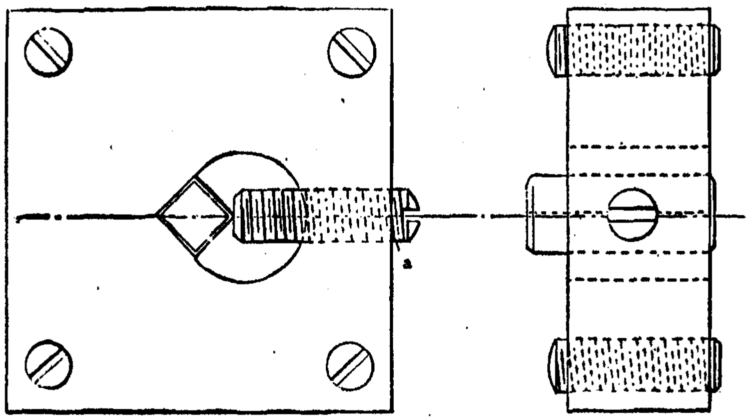

Fig. 81. — Cast-iron Piece.

finished about ¼ inch square. Next a 3/32-inch hole is drilled in the middle and countersunk with a center reamer; and after the corners have been nicely rounded the gage is ready to harden.

To get the best results, it should be packed and the ends hardened in oil, as the oil will give a nice dead-black finish. Next two adjacent sides are ground on a surface grinder and lapped square.

Now we are getting where things *must* be right, so we will test with a knife edge square, drawing the fingers crosswise over the gage and then drawing the square endwise and noting the marks made by the blade in the moisture left on the surface by the fingers. This, in our opinion, is better than the light test.

We are now ready to finish the ends, and for this a piece of

cast iron 3 inches square and ¾ inch thick, as shown in Fig. 81, will do, care being taken to have the corner screws tapped in square and a snug fit, and the corner for the gage scraped to a good surface, for we must be able to remove the gage and return it absolutely to the same position. Next, this lapping jig is placed on a true mandrel, secured by a screw *a*, and the corner screws adjusted on the lathe center with a test indicator. We now place the jig on the surface grinder with the gage in position, as shown, and grind one end.

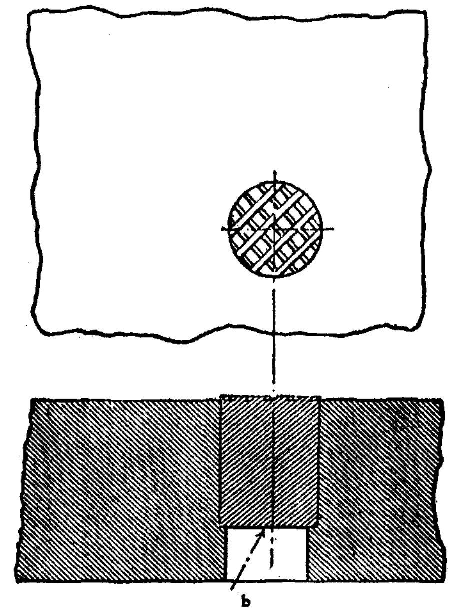

Fig. 82. — Plate Required for End Lapping.

The plate in Fig. 82 is now needed. It is of cast iron with a ½-inch brass plug *b* driven securely in, planed off 1/16 inch above the surface and checked as shown. A drop of oil and a pinch of flour of emery (diamond dust is better) are placed on plug *b*, the jig is placed in position, and the gage dropped into place and secured by screw *a* with the ground end down, care being taken not to turn *a* so tight as to spring the jig.

It becomes interesting now. Tapping the gage lightly with a piece of brass rod to seat it on the lapping plug, it is lapped until the surface is cleaned up, when it is removed from the jig and tested with the knife edge square, notice being taken of the way the jig is out; the corner screws are then adjusted to correct the error and the lapping process is repeated. This is kept up until the end is square with both finished sides, and it must be right for any error here will be doubled when the outer end is finished.

When the end is square and a suitable surface secured, the jig is placed on the surface grinder, the other end ground, leaving about .00025 inch to finish — or less if the wheel is fine and true — and the lapping process is repeated. This time as the jig is adjusted we have to deal with the length only, but great care must be taken now. New abrasive material must not be put in the lapping plug when near the finish, or scratches will be made that cannot be taken out without making the gage too short; and the work must not be handled, as it will expand with the heat of the hands, so a small stick is thrust into the hole at this point to hold it while measuring.

One of these little blocks of steel that is *right* may not look very much to the average eye, but it is a work of art nevertheless.

Lapping and Testing Small Holes

The following relates to bushings that are not to be ground out but worked as they come from the hardener. There is one

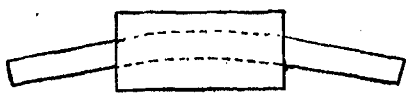

Fig. 83. — Seemingly Straight Hole.

point in this work that is not given enough attention in small holes, say from .10 inch down as small as you can go, for the small ones are the easiest to be deceived with. Fig. 83 shows (exaggerated) what a seemingly straight hole would test up to in the gage, Fig. 84, to be described later. In lapping this hole it is very easy to say it is small in the center, and ease it there so that the fit seems to be even. Think of a drill running in such a hole — and there are lots of them, and gages, too, with a hole of this kind.

Figure 85 is a lap which gives satisfaction. A taper pin that fits into a taper hole gives a good, solid adjustment for wear. There are two slits starting from a hole drilled through the lap

about ⅛ inch from the end, and extending to another hole which is at a sufficient distance to give an easy spring to the lap. Put two slits in laps, .1875 down to .080, using a fine fret-saw blade. Laps below .080 ream out, so there is only a thin shell left that will expand without slitting when the arbor is tapped in. In holes too small for taper pins drawn brass wire may be used. To enlarge it use a hard steel V-block, the "V" being the light size to allow a flat piece to be placed on the top of the wire and struck with a hammer; sometimes the wire is turned if it can be done conveniently. Laps above .1875 inch can be used on the taper arbor held in the chuck. The metal for outside lapping should

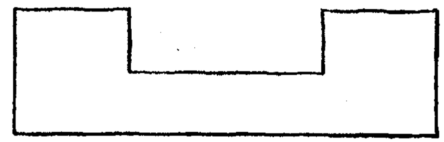

Fig. 84. — Gage for Fig. 83.

be gray iron for roughing and pure copper for finishing. Abrasives from good manufacturers run very close to what they are sold for. Brass or gray-iron is full of dross which will leave marks on highly finished steel. In lapping small holes finish with drill rod tinned over and trued off.

The bell-mouthing of holes by lapping is caused by two things. A lap flooded keeps the ends of the hole always charged heavily;

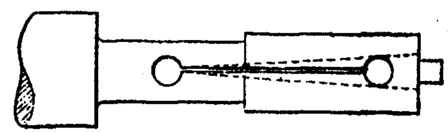

Fig. 85. — Lap for Small Holes.

a lap run dry, as the tightly fitting portion comes out of the hole, expands — and it does so when flooded — and putting a greater pressure on a narrowing surface, produces a bell mouth. This works both ways; for a lap is large and must be compressed as it enters the hole, which helps increase the bell mouth. The nearer solid a lap is, the less trouble there is in using it, and Fig. 85 comes as near as you can make an adjustable lap for small sizes. Leave 1/16 inch on each side of the bushing for bell mouthing, and when you grind it to length you will find that the hole is a little small at each end and will have to be touched out a little in most cases.

The length of the lapping part of the lap for a hole that is finished to length should be one-half of the length of the hole. In lapping a hole that is finished to length use a lap that is about one and a half times the length of the bushing and charged by rolling between two hard, flat surfaces, then wiped almost dry by the hand. This lap shows us that the hole is not made hollowing with the narrow lap.

A simple test to find the error in a piece like Fig. 83 is to rough lap the hole and then turn a pin in the lathe long enough to stick through to test with an indicator. With very small holes take a piece of gray iron, Fig. 84, and plane a channel wide and deep enough to let the pin rest on the flat surface. If the pin lies flat on this surface before it is put in the bushing, it should while in the bushing rest with the ends sticking out about ½ inch.

Use half kerosene and lard oil for a lubricant, and diamond dust for small holes, or be satisfied with what carborundum will do, though this will make you renew laps, often.

Casting Lead Laps

The sketch, Fig. 86, shows a mold for casting lead laps. It is simply a wooden box to be filled with plaster of paris, and C is an

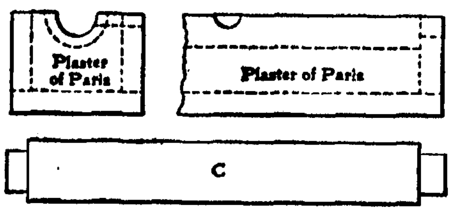

Fig. 86. — Mold for Casting Lead Laps.

arbor for pressing into the plaster to form the mold for the size of lap required. The ends of the box are cut to a ¾-inch semicircle and a groove is cut in the middle of one side for pouring. The box is filled with plaster of paris, and while this is still soft the arbor is pressed into it, and with the arbor in the mold the plaster is allowed to set. Then the arbor is taken out and the other half of the mold is made in the same way. The iron core upon which this lap is to be cast has numerous holes drilled part way into it to hold the lead firmly. The core is laid in its place and the halves of the mold are clamped together. The hole for pouring the lead should be on the center line, allowing the mold to be easily taken apart after the lap is cast. This mold can be used for casting many laps, and it requires but a small allowance for turning.

A Lapping Fixture for End Lapping

Figure 87 is a cast-iron lapping fixture with hardened steel shoes inserted in the bottom and held in place with hardened steel screws. These pieces must not fit tight at the sides. Piece *a* is pivoted on the lower screw, which must be a very good body fit and true; the top screw works in an elongated hole and has a head large enough for a good bearing.

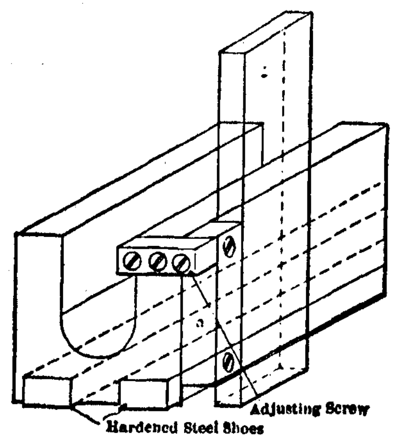

Fig. 87. — Cast-iron Lapping Fixture.

Piece B is to be lapped square on the ends, and is held in the position shown by the fingers of the right hand, so there will be a pressure diagonally toward the inside corner; use rubber tips on the fingers and they will give you all the grip necessary for the pressure down on the lap. This fixture will do a good job after a little practice with it, holding the work, and it makes a good angle iron for holding work to grind the ends square. The other side is left plain for thin pieces, which require lapping flat and square on the edges.

When lapping thin pieces look out for "plowing"; if this shows up the surface will be crowning. Lap lengthwise and a little diagonally, holding the work against the fixture with the fingers; if the work is very thin and long, use a flat strip between it and the finger. This fixture, if rightly made, can be trued off on the hardened shoes — which are above the surface, about $\frac{1}{16}$ inch — by placing it on the opposite edges and grinding the shoes off true when they have worn out of square with the sides by use.

If in doubt about the accuracy of the grinder chuck, place a couple of pieces on the chuck and spot them off true; place the fingers on them and up against the back rest, then grind the steel shoes off lengthwise.

A Shaker for Lapping Emery

It will be of interest to describe and illustrate an emery shaker that was designed and found a useful and very convenient addi-

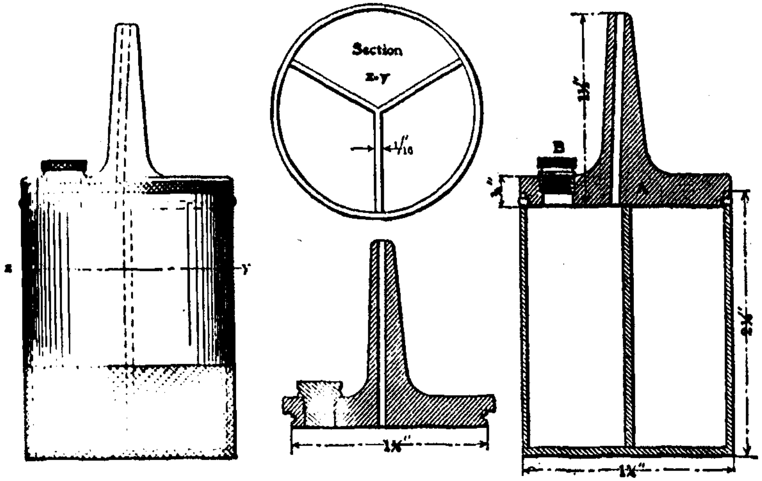

Fig. 88. — An Emery Shaker.

tion to the tool-room outfit, as it dispenses with the numerous dishes, cans and packages that are generally used to hold the various grades of emery required in lapping and polishing. The model, Fig. 88, was made from solid brass with three compartments, which was found most suitable for general work, although the device can be divided into six compartments if preferred. The partitions were cut from sheet brass and soldered in place. The body can be made from tubing, but a casting is better. The cap must be a good fit to prevent emery from passing the partitions.

The stem is drilled out of line at the base to clear the partitions, so that by turning the cap *A* each compartment in turn will be free to discharge the emery while the other compartments are closed. Plug *B* can be dispensed with, although it is convenient when refilling as it saves the trouble of removing the cap.

Outside of the compartments should be stamped the letters *F*, for fine; *M*, for medium; *C*, for coarse; and the cap should be graduated to indicate when it is in the right position to discharge, or when closed by stopping over partitions.

A Pair of Lapping Emery Stick Holders

Where there is considerable work to do on small dies, plenty of lapping is necessary to bring them back to shape after harden-

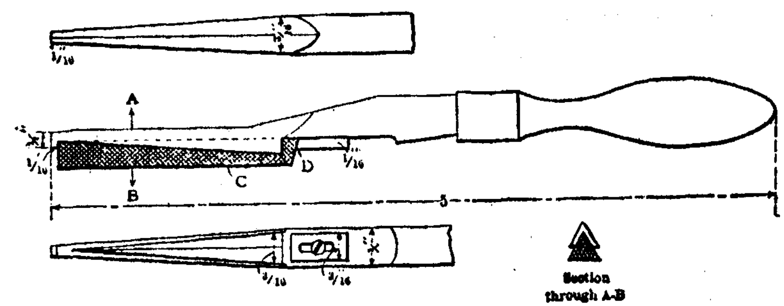

Fig. 89. — Emery Sticks for Lapping.

ing, and the ordinary emery sticks, when a little pressure is put upon them, break very easily. Where so many break, it is found a big waste to have a lot of short pieces that are almost useless, and so the holders can be made as shown in Figs. 89 and 90. With these most of the pieces can be used and besides more pressure can be put on them, with the result that the work is done quicker and better and there are not so many sore fingers.

The holder, Fig. 89, is for a triangular piece, and is made of tool steel. The emery stick is beveled off on the back so that the plate *D* holds it from falling out. The lip on the front end holds it from going forward, and when the piece is put into the holder one of the angles fits in the groove cut in the holder, so that prevents any side motion. It will suit any size of triangular piece, for all it has to do is just fit in the groove. It will be noticed that the groove increases in depth from the front end back to plate *D*, but is cut parallel to the body of the holder. The reason for cutting it away at the front end is so that one can see what he was doing, and this is very advantageous in many cases.

Figure 90 is for a square piece, and has a lip on the end the same as Fig. 89, but the emery stick is held in place by the side lips and screw *c*, which, being tightened up, draws the lips *E* together. It will be noticed that the holder is slotted so that the screw *c* can pinch the lips in on the emery stick. These lips are only ½ inch long, and the size of stick they will grip is ¼ inch. If a wider piece is required, all that is necessary is to grind it away till it fits between the lips. It is almost surprising how solidly the pieces are held in position, and the work of lapping, which every mechanic knows is so hard on the fingers, is made

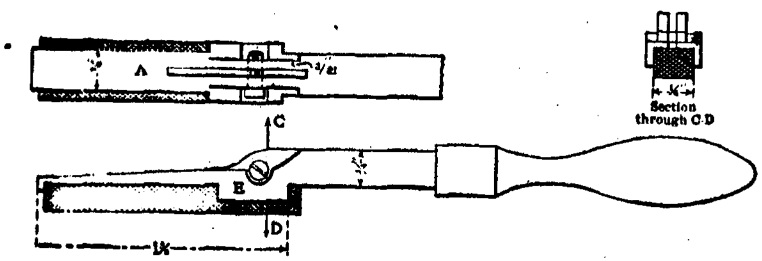

FIG. 90. — Emery Sticks for Lapping.

comparatively easy. They are not costly tools to make and the time taken to make them is soon gained on the work. Other pieces of emery sticks can be made to fit these holders for certain special jobs.

LEAD LAPPING A STEEL-LINED CYLINDER

We hear much about grinding machines nowadays, inside and outside grinders, surface grinders and grinders of all sorts; and as the producers and users of machinery become more skilful, the demand for and ability to construct more accurate and efficient mechanical appliances lead to an increasing use of abrasive processes. The grinding machine itself, in its many forms, comprises a distinct class of highly developed machinery, the history of which would, no doubt, be very instructive and interesting.

The accompanying sketch, Fig. 91, is of a "grinding machine"

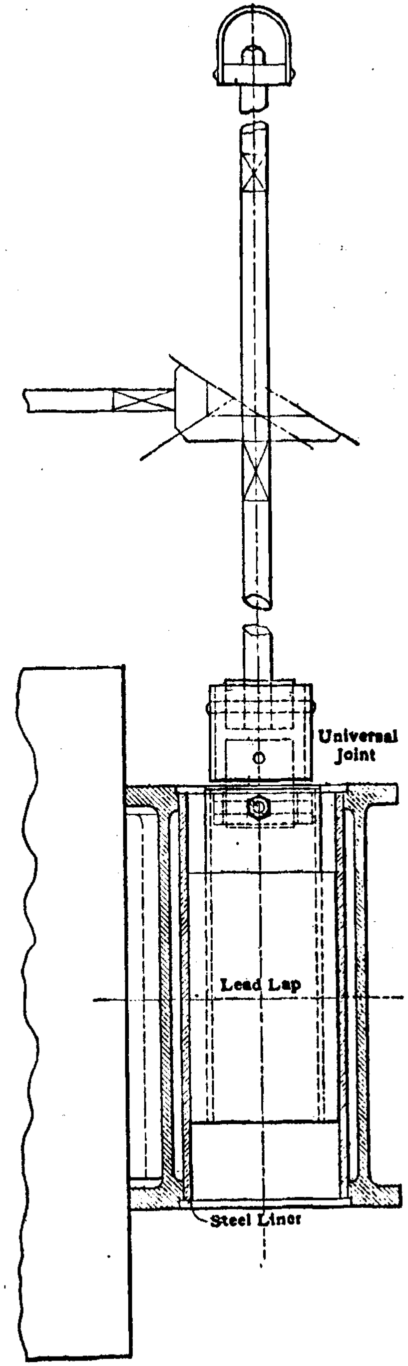

FIG. 91. — Grinding Machine for Cylinder.

used some years ago in producing smooth and accurate cylinders for compressing gas. The principle used, the lead lap, probably familiar to most readers, is doubtless one of, if not the chief, progenitors of the grinding machine.

An old Dallett portable drill was stripped of everything except the base, frame and gearing. A piece of shafting of the same diameter as the drill spindle, and of proper length, was key-seated its entire length; one end being attached by a universal joint to a piece of pipe, around which was cast the lead for the lap. This joint was made in the cheapest manner possible, of pieces of pipe, a piece of round iron and rough iron pins. To the other end of the shaft a loop was attached by a bolt upon which it turned easily. The lap was turned so it would slip easily through the cylinder as it left the boring mill, and was provided with four large grooves extending about two thirds the way down from the top, to conduct emery and oil.

The cylinder was bolted to one side of a large T-slotted cast-iron block, with the Dallett drill on the top, and the shaft put in, in place of the spindle, and centered roughly with the cylinder by the eye. A light block and tackle were attached to the loop at the top of the shaft and to the ceiling of the shop, the usual portable drill drive connected up, and a can of oil and box of loose emery being provided, everything was ready for beginning operations with the internal "grinding machine."

The speed and accuracy with which the work was accomplished by this contrivance would probably be surprising to some. From three to four hours sufficed to make a 7 x 18 cylinder, lined with forged steel, perfectly smooth and of uniform diameter within .00025 inch. The lap would grind out about four cylinders without renewing, when the lead would be recast on the pipe and turned to size again. Of course there was a few thousandths variation in the sizes of the cylinders, which is obviated in improved machines for this kind of work.

Diamond Power and its Use in the Machine Shop

The diamond used for this purpose, costing $85 per carat, is an inferior grade of diamond, not so hard as the black diamond used for drills and truing emery wheels, and not of a clear and perfect structure to permit it to enter the gem class. Many of them

are a mixed black and white, others yellow and some pink; many are clear but flaky. Then there is the small debris from diamond cutting, which is reduced to powder and sells somewhat cheaper; but we find it more economical to use the above and powder it ourselves, as the debris from diamond cutting is of a flaky nature and does not charge into the lap so well.

Assuming we have 25 carats to reduce to powder, we proceed as follows:

Into a mortar, as shown in Fig. 92, we place about 5 carats,

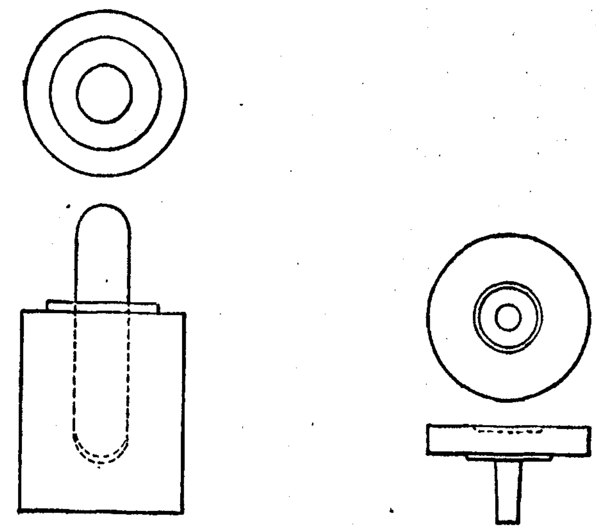

Fig. 92.—Mortar for Pulverizing Diamonds.

Fig. 93.—Copper Lap for Small Drills.

using an 8-ounce hammer to crush it. It takes from four to three minutes' steady pounding to reduce it to a good average. Scrape the powder free from the bottom and the sides and empty in one-half pint of oil. The oil is the best olive oil obtainable, and is held in a cup-shaped receptacle that will hold a pint and one half. The 25 carats being reduced to powder, and in the oil, we stir it until thoroughly mixed, and allow to stand five minutes; then pour out to another dish. The diamond that remains in the dish is coarse and should be washed in benzine and allowed to dry, and should be repounded, unless extremely coarse diamond is desired. In that case we label it No. 0. Now we stir that which has been poured from No. 0, and allow to stand ten minutes. Then pour off into another dish. The residue will be No. 1. Repeat the operation, following the table below.

The settling can be put into small dishes for convenient use, enough oil staying with the diamond to keep it the consistency of paste. The dishes can be obtained from a jeweler's supply house.

Table for Settling Diamond

To obtain No. 0 — 5 minutes.
To obtain No. 1 — 10 minutes.
To obtain No. 2 — 30 minutes.
To obtain No. 3 — 1 hour.
To obtain No. 4 — 2 hours.
To obtain No. 5 — 10 hours.
To obtain No. 6 — until oil is clear.

Diamond is seldom hammered; it is generally rolled into the metal. For instance, we desire several pieces of wire of various

Fig. 94. — Roll for Charging Lap with Diamond.

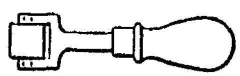

Fig. 95. — Roll for Charging Lap with Diamond.

diameters charged with diamond for use on die work. We place the wire and a small portion of the diamond between two hardened surfaces, and under pressure roll back and forth until thoroughly charged. No. 2 diamond in this case is generally used. Or you can form your metal any desired shape and apply diamond and use a roll, as Fig. 94, to force the diamond into the metal. You then have a file which will work hard steel, but remember the moment you crowd your diamond file, or lap, you strip it of the diamond, and it is consequently of no use. It is to be used with comparatively light pressure.

Copper is the best metal. It takes the diamond readily, and retains it longer than other metals; brass next, then bessemer steel. The latter is used when you wish to preserve a form that is often used.

For sharpening small, flat drills, say 0.008 to 0.100 (metric), a copper lap mounted on a taper shank, as Fig. 93, and charged

on the face with No. 2 diamond, using pressure on the roll, makes a most satisfactory method of sharpening drills.

The diamond lasts for a long time if properly used, and there is no danger of drawing the temper on the drill. It is much quicker than any other method of sharpening.

To change the lap we should use the roll Fig. 95, supported on a T rest pressing firmly against lap, being careful to have the roll on the center; otherwise, instead of charging the lap we should be grinding the roll. The diamond may be spread either on the lap or on the roll, and the first charging usually takes twice the amount of diamond that subsequent charging takes. To avoid loss of diamond, wash the lap in a dish of benzine kept exclusively for that purpose. This can be reclaimed by burning the metal with acids, and the diamond can be resettled.

For the grinding of taper holes in hard spindles or for position work in hard plates, where holes are too small to allow the use of emery wheels, No. 1 diamond does the work beautifully. Or if you wish to grind sapphire centers or plugs as stops, etc., a bessemer lap made in the form of a wheel and charged with diamond on the dimeter does the work nicely.

There are many ways which will suggest themselves where diamond powder can be used to great advantage. Nos. 5 and 6 diamond are used on boxboard laps, mounted on paper plugs or chucks, and the diamond smeared on with the finger. It is run at high speed and used for fine and slow cutting, which also gives a high polish.