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GRADUATING ENGRAVING AND ETCHING

A TREATISE ON THE MACHINES AND METHODS EMPLOYED FOR GRADUATING STRAIGHT AND CIRCULAR SCALES AND ENGRAVING VARIOUS FORMS OF NAMEPLATES, BY ETCHING AND CUTTING PROCESSES

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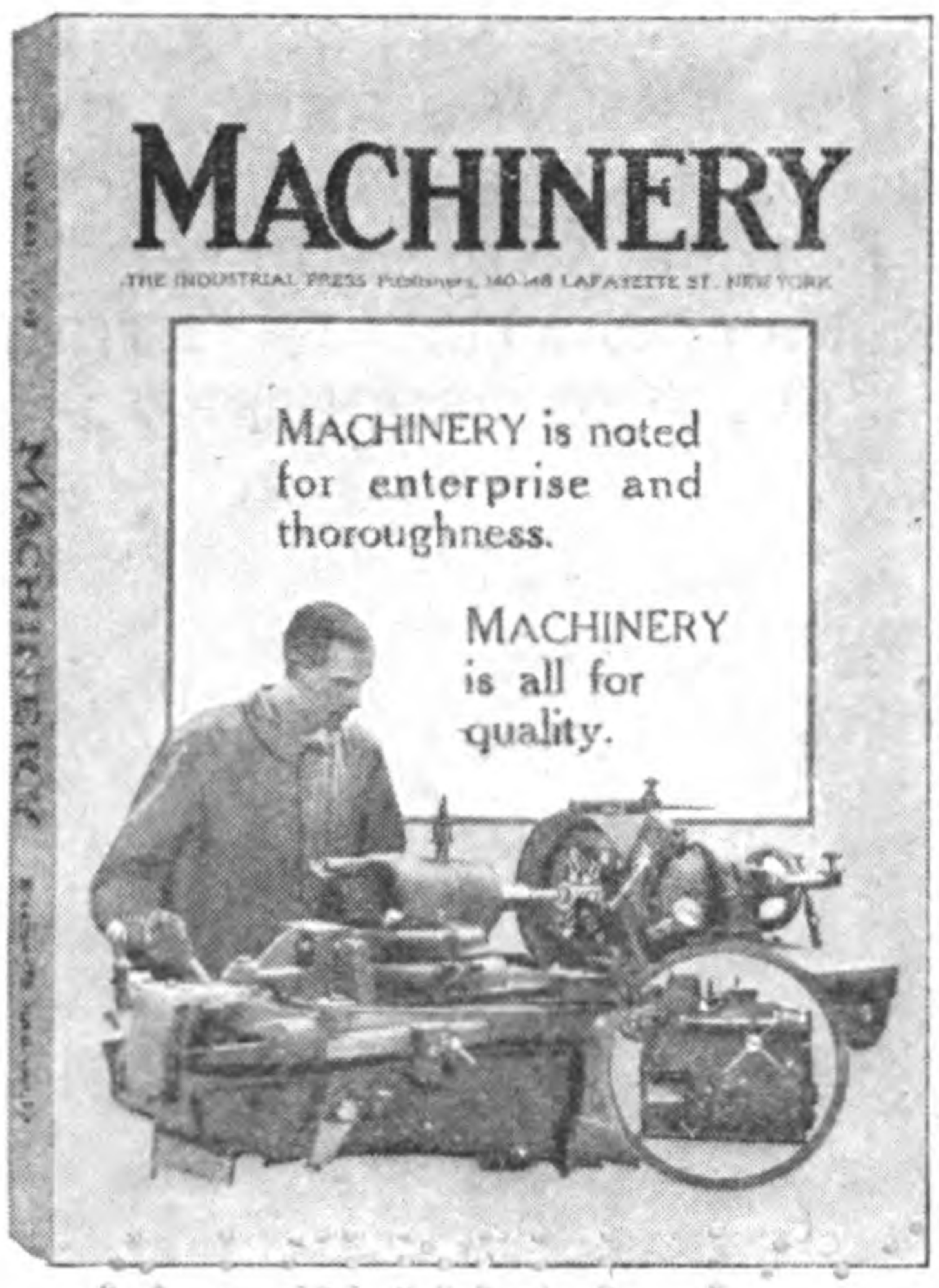

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GRADUATING, ENGRAVING AND ETCHING

CHAPTER I

GRADUATING MACHINES AND THEIR USE

CUTTING graduation marks and figures that indicate the values of successive graduations may involve three distinct operations. Graduation marks may be cut directly in the metal, or an acid "resist" may be applied to the steel and the graduation marks cut in this protective coating. When the latter method is employed, the marking of the graduations is done by immersing the work in acid so that the surface of the metal from which the resist has been removed by the graduating tool may be "cut" by the etching solution. In any case, a graduated scale would be incomplete without figures to indicate the values of successive graduations, and these may be cut in several different ways. The simplest method would be to cut the figures by hand, but such a procedure would involve considerable time and expense. A better way is either to do the work on an engraving machine, the operation of which is controlled by a pantograph mechanism and master copy, or to use a graduating machine which is designed in such a way that it can also be used for cutting figures and other irregular designs, such as trademarks, etc. As in the case of cutting the graduation marks, the figures may be cut directly in the metal or they may be cut in a protective coating applied to the metal and etched by immersing the work in acid. Similar methods may be employed for trademarking the work, but where there is a considerable amount of detail in the design it may be more economical to use certain labor-saving methods, to which reference will be made later.

Some confusion exists as to the use of the terms graduating, engraving and etching. These operations are decidedly different, but as the same general result may be obtained by graduating or by a combination of graduating and etching, and by engraving or by a combination of engraving and etching, these terms have come to be used interchangeably, which is incorrect. It is the purpose of this treatise to give a comprehensive description of various methods of graduating, engraving and etching, and to explain the different classes of work for which each of these methods is especially adapted.

Methods of Graduating. The degree of accuracy required in graduating varies considerably with different classes of work. The instruments used in connection with astronomical observations require the greatest degree of precision obtainable, while the graduations on surveying and nautical instruments, machinists' and toolmakers' scales and protractors, and similar tools and instruments, do not require the extreme accuracy of the astronomical instruments, although such graduations must be very accurate. The type of machine or tool used for graduating and the method of producing the graduation marks or lines varies with the different classes of work, depending upon the degree of accuracy necessary and the form of the parts to be graduated. The extent to which graduating is done or the quantity of work handled may also affect the type or design of the machine or tools used. The work of graduating may be divided into two branches—the method of spacing, and the means for making suitable marks or lines upon the parts to be graduated.

Spacing Methods. The machines used in laboratories and by tool and instrument manufacturers, for graduating various kinds of straight scales, may be classified as the precision screw type and the pantograph type. The former is equipped with a very accurate lead-screw, which, by means of an indexing or spacing mechanism, is rotated an amount depending upon the spacing required, and as this screw actuates the work-holding table, a tool that is given a cross-movement makes graduation lines either in a "resist" or directly upon the work. The pantograph machines have a pantograph mechanism which serves to reproduce, on a smaller scale, the graduation lines or figures that have been previously cut in a pattern or master scale. Machines of the two general types referred to are generally used for linear graduations, although some designs are also adapted for circular graduating. A design intended especially for circular work has an accurately cut worm-wheel connecting with a circular work-table, and a meshing worm which is rotated by an indexing or spacing mechanism, in accordance with the circular spacing required.

Formation of Graduation Lines. The marks or lines which represent divisions or spaces on graduated scales, etc., may be formed by the etching process, by the direct-cutting action of a tool, or, for some grades of work, by the stamping or impression process. With the etching process, the part to be graduated is first covered with some acid-resisting material or "resist," as it is called, and then the lines or figures are cut into this resist by a mechanically guided graduating tool, thus exposing the metal wherever these lines or figures are made. An etching acid is then applied, and, wherever the metal is exposed, the acid eats into the surface and forms the division lines. When very fine graduation lines are needed, the general practice is to employ the direct-cutting method, since the marks obtained by a very sharp-pointed tool are finer and more accurate than can be obtained by the etching process. There are two general types of cutting tools, one of which operates with a plain draw stroke, whereas the other is a rotary tool and revolves at a speed of about from 8000 to 10000 revolutions per minute. Diamond points are also used for cutting very fine graduation lines, the diamond being drawn across the work without a rotating movement.

Screw Type of Linear Graduating Machine. A linear dividing or graduating machine of the screw type, which is adapted for precision work on scientific instruments or for other work in which a high degree of accuracy is necessary

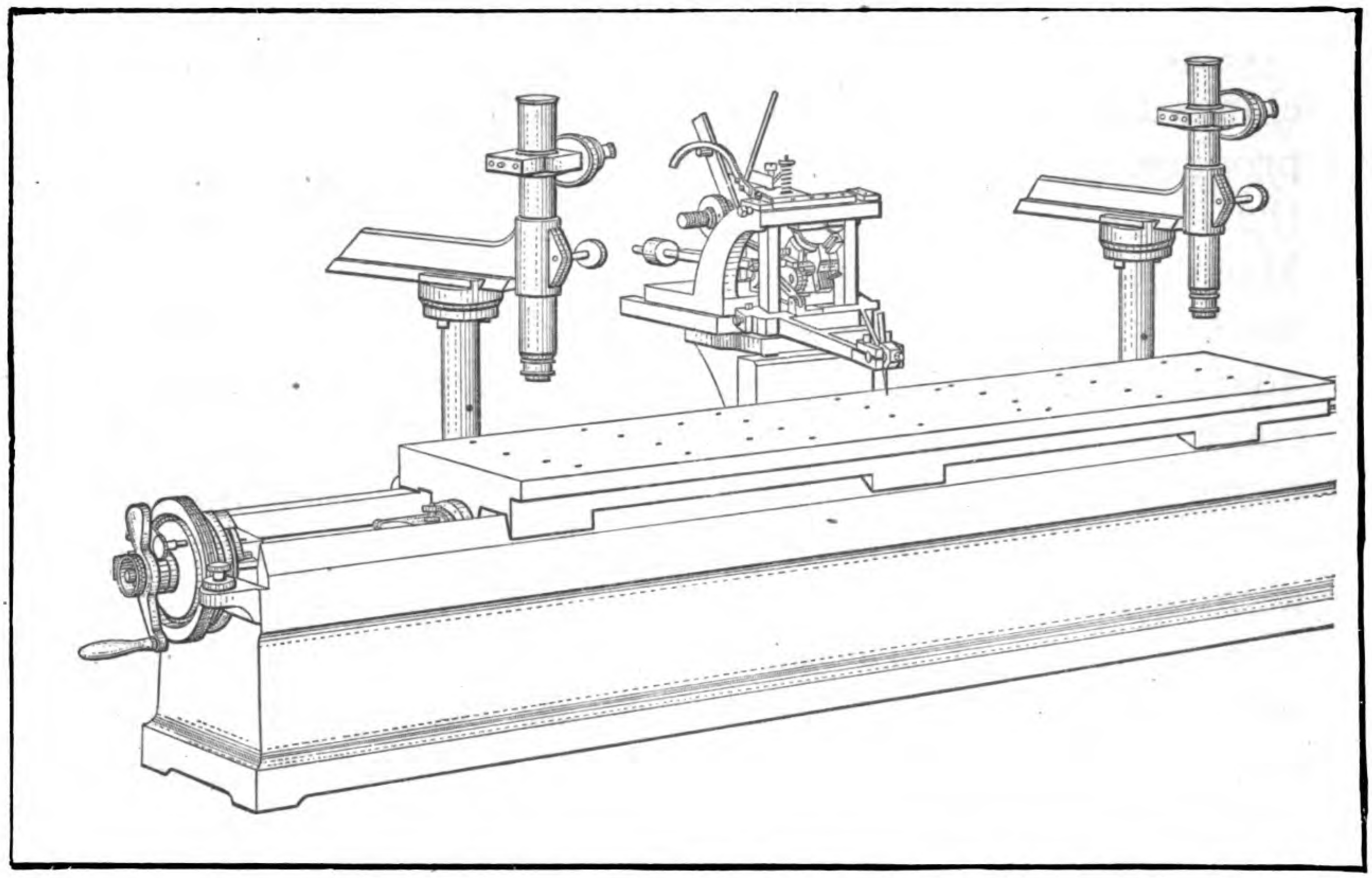


Fig. 1. Hand-operated Linear Dividing Engine or Graduating Machine of Precision Screw Type

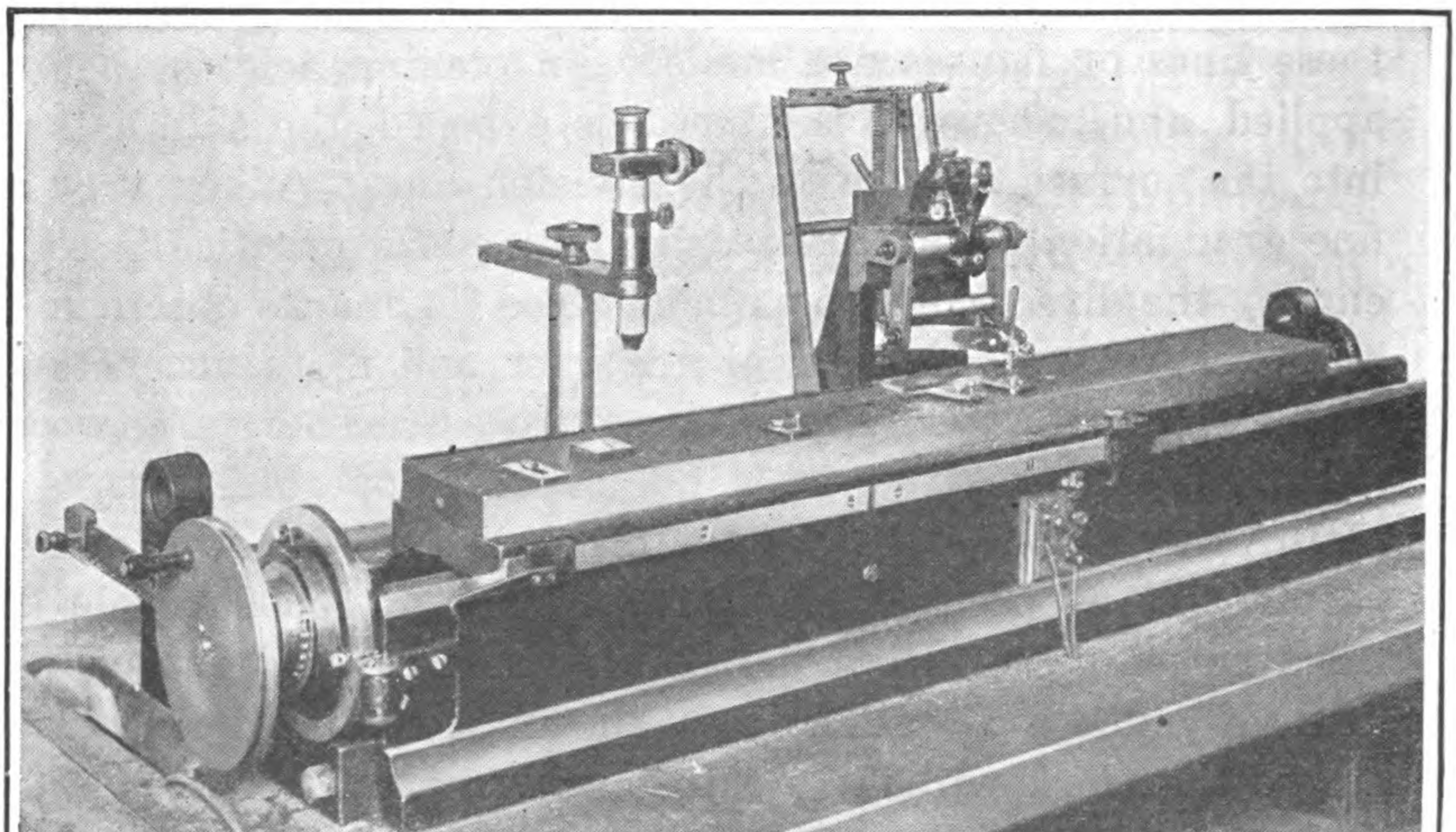


Fig. 2. Power-driven Linear Dividing Engine or Graduating Machine similar in Design to Machine shown in Fig. 1

is shown in Fig. 1; and Fig. 2 illustrates a power-driven machine of the same general design. The bed of this machine is provided with planed ways upon which a work carriage is mounted. This carriage is traversed by a lead-screw located inside the bed, and in the case of the hand-operated machine, this screw is turned by the small handwheel at the left-hand end of the bed. After each movement of the carriage has been completed, a tool supported by the tool-head at the back of the machine makes a graduation mark on the work which is secured to the carriage. The handwheel at the end of the lead-screw is provided with a graduated dial, each space of which corresponds to 1/200 millimeter. Secured to the handwheel is an adjustable stop which may be set to obtain the required distance between consecutive graduation lines. This stop engages cams at the front and back of the handwheel, which are brought into position to engage the limit stop, by means of a thread on the circumference of the handwheel meshing with small wormwheels that actuate the cams. The engagement of the thread on the handwheel with the wormwheels may be so adjusted that the limit stop comes into contact with the cams after part of a revolution of the handwheel or after more than one complete revolution according to the requirements of the work.

Operating the Machine. In operating the machine, the handwheel is turned back until the stop comes into contact with one of the cams. This backward movement is effected without turning the lead-screw on the machine; then the handwheel is turned forward and in this direction a ratchet and pawl causes the lead-screw to be locked to the handwheel so that the screw is turned, and advances the carriage and work until the limit stop comes into contact with the cam at the opposite side of the handwheel. Then the operator pulls forward a small hand-lever on the tool-head, which draws the tool across the work and makes a graduation line.

The machine is provided with means for making graduations of different lengths. For instance, it may be necessary to make each fifth graduation mark longer than adjacent marks, each tenth mark still longer, etc. On this machine, such variations in length are effected by means of three stop-screws which come into contact with a notched wheel, the movement of the tool and the length of the graduation mark being limited by the engagement of one of these screws with the wheel. At each stroke of the toolpost, the three sections of this wheel are advanced by means of a ratchet and pawl, and the three wheel sections may be adjusted in relation to each other so that the desired relation is obtained between the position of the notches and the intermediate faces on the different wheels. In this way, the stop-screws come into contact with the wheel on either faces or notches as required, thus varying the lengths of the graduation lines according to requirements. In addition to its use for graduating, this machine may also be employed as a comparator, and for this purpose two microscopes are provided which enable the position of graduations on a scale to be accurately compared with the position of graduations on a standard scale.

Calibrating the Lead-screw. From the preceding description, it will be apparent that the degree of accuracy obtained with a machine of this kind is dependent upon the precision of the lead-screw. In making the machine, the greatest possible care is exercised in cutting the screw and nut, and the bearing of the nut on the screw is then perfected, as far as possible, by a lapping operation performed by introducing fine rouge or some similar abrasive into the nut. This does not provide for correcting inequalities in the lead of the thread, and, where a high degree of accuracy is necessary, the lead-screw is calibrated. For this purpose, a standard scale is mounted on the carriage, and the carriage is then advanced through suitable increments of length, as shown by the divided dial at the left-hand end of the lead-screw. After each movement of this kind, the amount of travel is noted by referring to the standard scale on the carriage with a microscope. The results obtained in this way are plotted on a chart and either of two conditions may be found: It may be that there is a uniform accumulated error extending from one end of the screw to the other, or it may be that the error is irregular. In either case, the same method of compensation is employed. Secured to the nut on the lead-screw is a short finger extending down into the groove of a guide placed inside the bed of the machine. In the case of an accumulative error resulting in a gradual increase in the lead of the lead-screw,

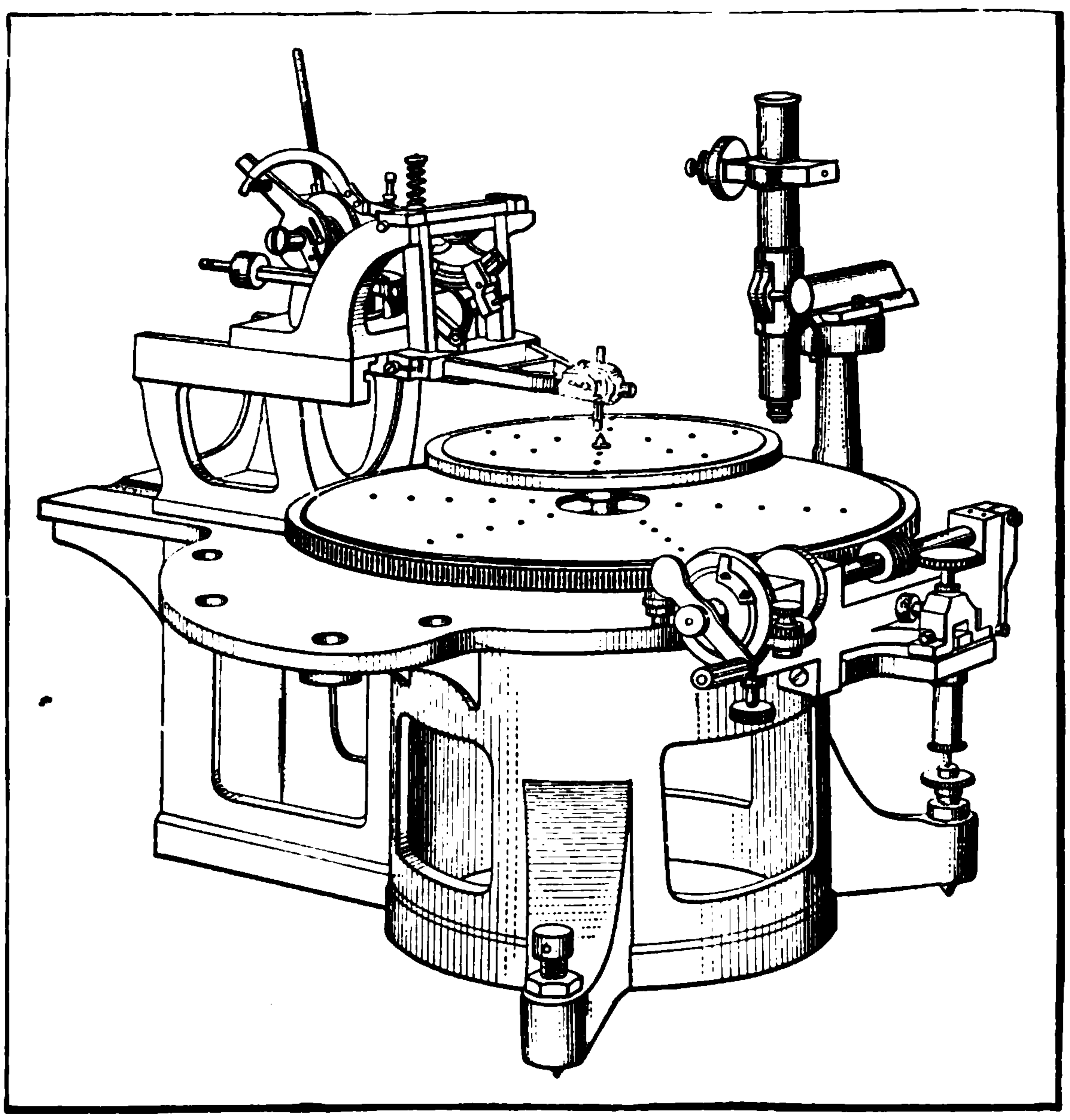


Fig. 3. Hand-operated Circular Dividing Engine or Graduating Machine

this guide is set at such an angle that the movement of the finger in the guide will turn the nut back slightly, thus compensating for the increase of lead. If the accumulative error were such that the lead gradually decreased, the nut would be turned forward in order to advance the movement of the carriage instead of to retard it. In cases where the error in the lead-screw is irregular, the lead being first too long and then too short, the same method of correction is employed, except that the guide groove is given a suitable curve of irregular form, instead of having a straight guide set at an angle.

Circular Dividing Machine. Fig. 3 shows a dividing engine for graduating circular dials and other work of similar form. The general principles governing the operation of this machine are the same as for the linear dividing engine already described, except that the machine shown

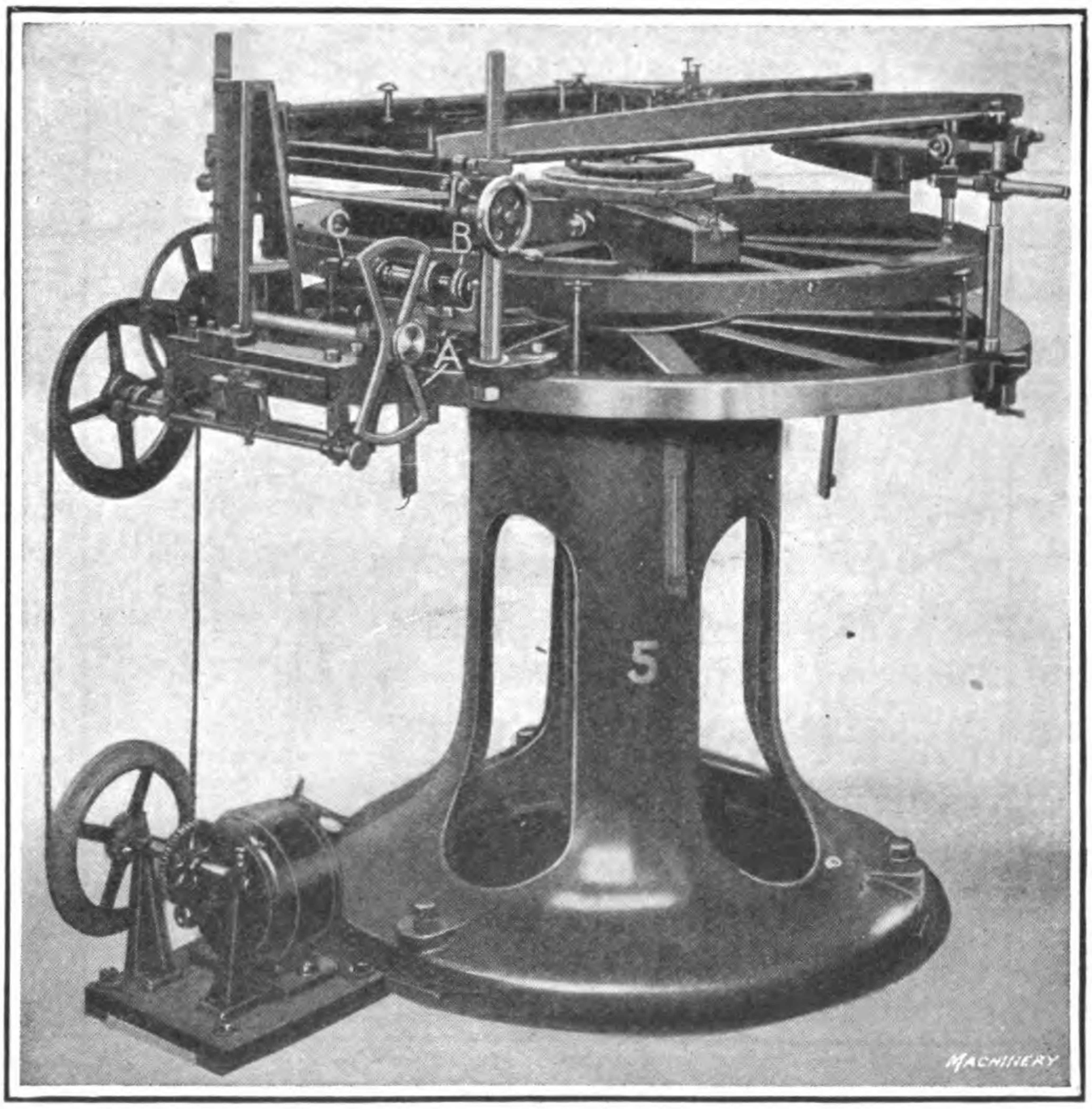


Fig. 4. Power-driven Circular Dividing Engine or Graduating Machine

in Fig. 3 has been designed especially for circular work. A circular dial mounted on a pivot is used instead of a carriage traveling on straight ways on the bed, and rotation of the dial is effected by a worm which meshes with worm-wheel teeth cut into the periphery of the dial. The worm that governs the rotation of the dial is carried by a shaft, on the end of which there is a handwheel and stop mechanism for limiting the space between the graduations, this mechanism being of the same form as in the linear machine. The tool for performing the graduating is carried by a toolpost and head of the same form as those used on the machine for graduating straight work. Some machines are so designed that they may be used for either linear dividing or circular dividing, there being a lead-screw for linear work and a circular table for dividing arcs or circles.

Automatic Circular Dividing Engine. For graduating the dials on sextants and other surveying and scientific instruments, C. L. Berger & Sons, 37 Williams St., Boston, Mass., have made the special circular dividing engine shown in Fig. 4. In constructing this machine, advantage has been taken of every means that would tend to give greater accuracy of the graduations on the work. For instance, the machine is housed in a room with double walls having the space between the walls packed with fiber; in this way the machine and work can be kept at practically a uniform temperature and errors due to expansion and contraction are avoided. Working with this degree of care, circular scales are graduated which are guaranteed not to have an error exceeding three seconds; in many cases the actual error is not greater than 1½ seconds of arc.

Circular scales are usually divided into 360 degrees; each degree is subdivided into 60 minutes, and each of these minutes is further subdivided into 60 seconds. This is known as the sexagesimal system. Attempts have been made to divide the circle into 400 degrees, that is, according to the centesimal system, thus making each quadrant susceptible of decimal division. It is difficult to apply the decimal system, chiefly because the circle with its commonly employed sexagesimal system of graduation is intimately connected with time, and this system lends itself to the making of calculations in connection with the division of hours into minutes and seconds. The degree has been decimally divided, and this has been found useful in laying down railway curves, due to its correspondence with the decimal division of the measures in use. The circular dividing engine shown in Fig. 4 is adapted for graduating circles in either the sexagesimal or centesimal system.

In precision circular graduating it is of importance to have the work held in a truly horizontal plane and also to have the work concentrically mounted with the worm-wheel of the dividing engine. To secure this condition, a special form of level is used, the method of employing it being illustrated in Fig. 5. This level is supported by a

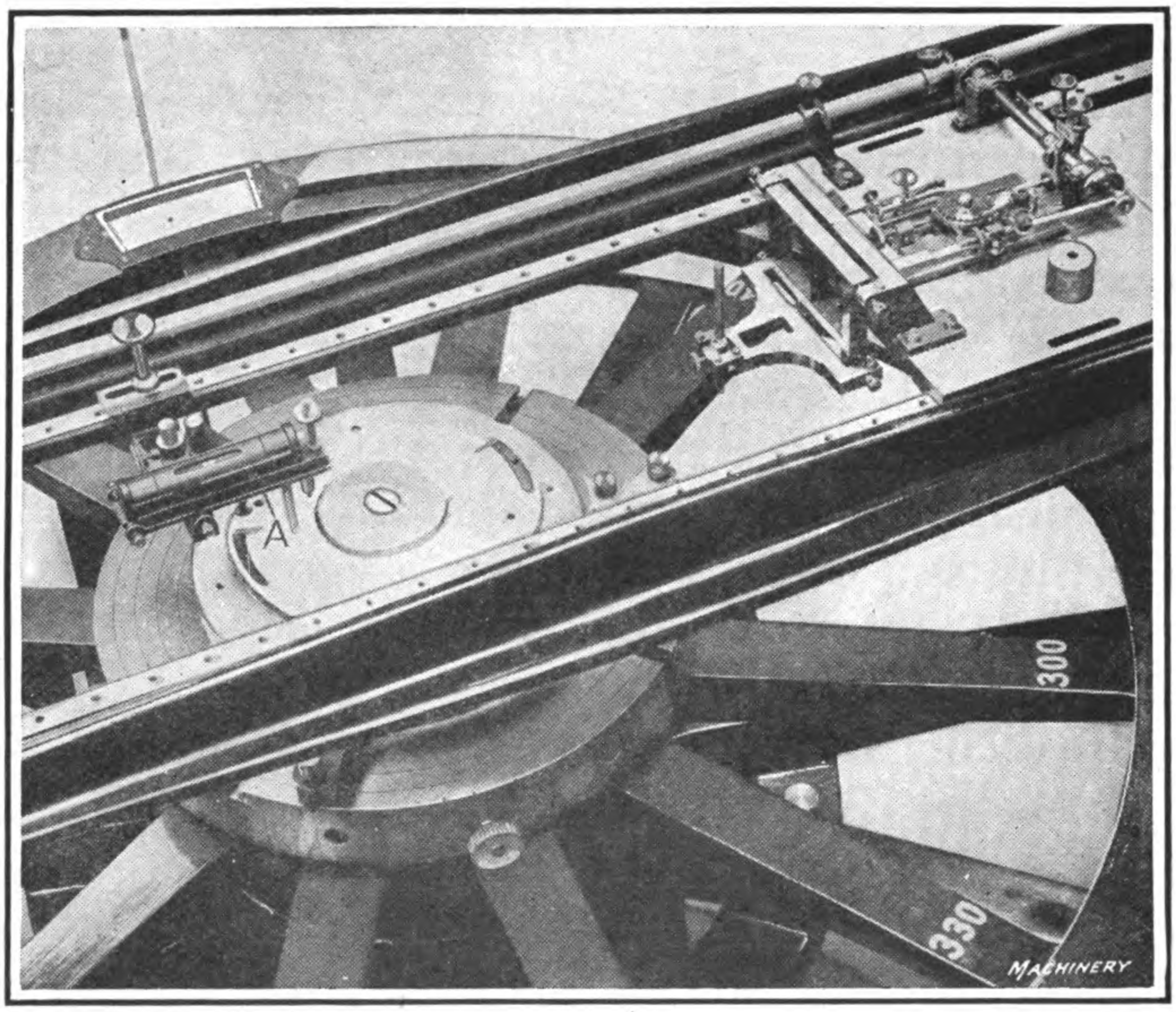


Fig. 5. Method of adjusting Work on Machine shown in Fig. 4

bracket screwed to the frame of the graduating machine, and the bar *A* that supports the level tube is pivoted to the main bracket.

At the opposite end of the bar from the pivot, it will be seen that there is a pin that bears against the surface of the work to be graduated; and after the level has been set up in this way the work is rotated in contact with the pin. Under these conditions any marked deflection of the bubble in the level tube indicates lack of accuracy in setting up the work, and suitable adjustment must be made until the test may be made without deflection of the bubble. This is a severe test because the level used for this purpose is extremely sensitive.

After setting up the work and making all adjustments of the machine, the operator leaves it and does not start the machine running until the next morning, because while setting up the work the heat of his body raises the temperature of both the machine and the work somewhat above normal, and as a result there is a gradual contraction until the normal temperature is reached, which would introduce inaccuracies into the work. The next morning he comes into the room, starts the machine up and leaves before there is time for the heat from his body to cause any serious amount of expansion. The machine runs automatically until the graduating operation has been completed, when an automatic stop is tripped, which disengages a clutch that transmits power from the driving motor.

Mechanism of the Circular Dividing Engine. A brief description of the Berger graduating machine will be given. It will be seen in Fig. 4 that the drive is provided by an individual motor bolted to the floor, and the work-table is rotated by a worm meshing with worm-wheel teeth cut in the periphery of the table. Graduations are cut by a reciprocating tool which cuts on the draw stroke and is lifted clear of the work on the return stroke. It will be obvious that indexing and graduating operations take place alternately, and this result is obtained as follows: From the first driving shaft power is transmitted through gearing to an intermediate shaft, on the right-hand end of which there is a double segment gear *A* which meshes with pinion *B* carried at the rear end of the shaft carrying driving worm *C*, that engages the worm-wheel on the work-table. While the segment gear is in mesh with the pinion, it causes driving worm *C* to rotate, and this indexes the work. During this time the graduating tool is idle; but when the segment gear runs out of engagement with the pinion, the work has been brought to the desired position, and at this time the graduating operation may be performed. Extending across the top of the machine is a shaft *D*, best shown in Fig. 6, which transmits power to the tool carriage *E*. The machine is used for graduating circles on dials of various diameters, and to adapt it for handling these different sizes of work provision must be made for setting the tool at various distances from the center of rotation of the table on which the work is held. This is done by having the tool carriage mounted on a slide so that its position may

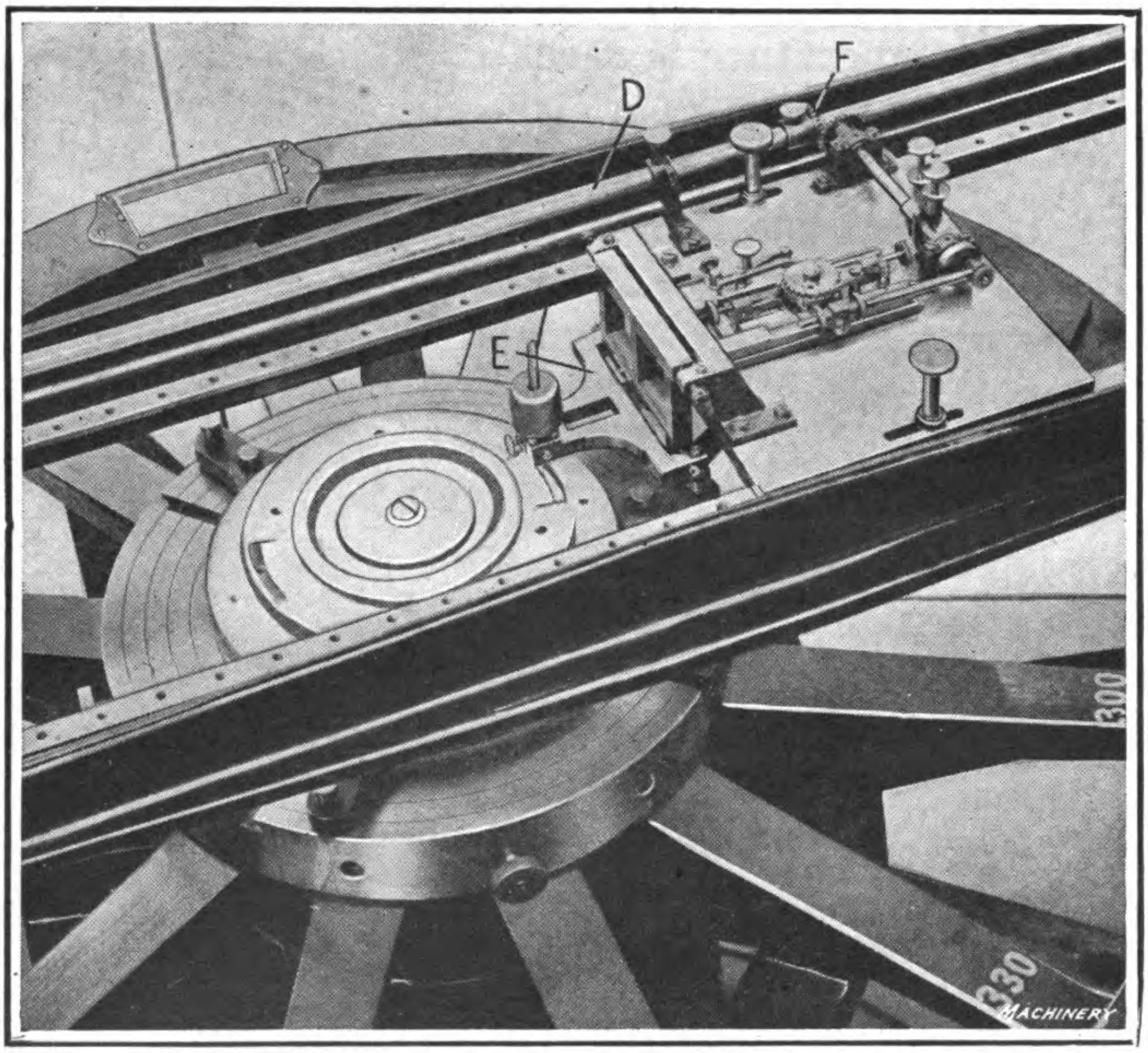


Fig. 6. Close View of Tool Carriage Mechanism of Graduating Machine shown in Fig. 4

be adjusted as required; and to transmit power to the carriage in any position, the bevel pinion *F* on the driving shaft is so arranged that it may be slid along the shaft and secured in any position by a capscrew. This bevel pinion transmits power to a cross-shaft which, in turn, operates a link mechanism under the carriage that gives the tool its reciprocating motion. The tool cuts on the draw stroke and is lifted clear of the work on the return stroke. As in the case of the Geneva dividing engines, to which reference has already been made, means are provided on this machine for cutting graduation marks of different lengths at any required intervals. This is done by the same arrangement of notched wheels and screws used in the Geneva machines, operated by a ratchet mechanism.

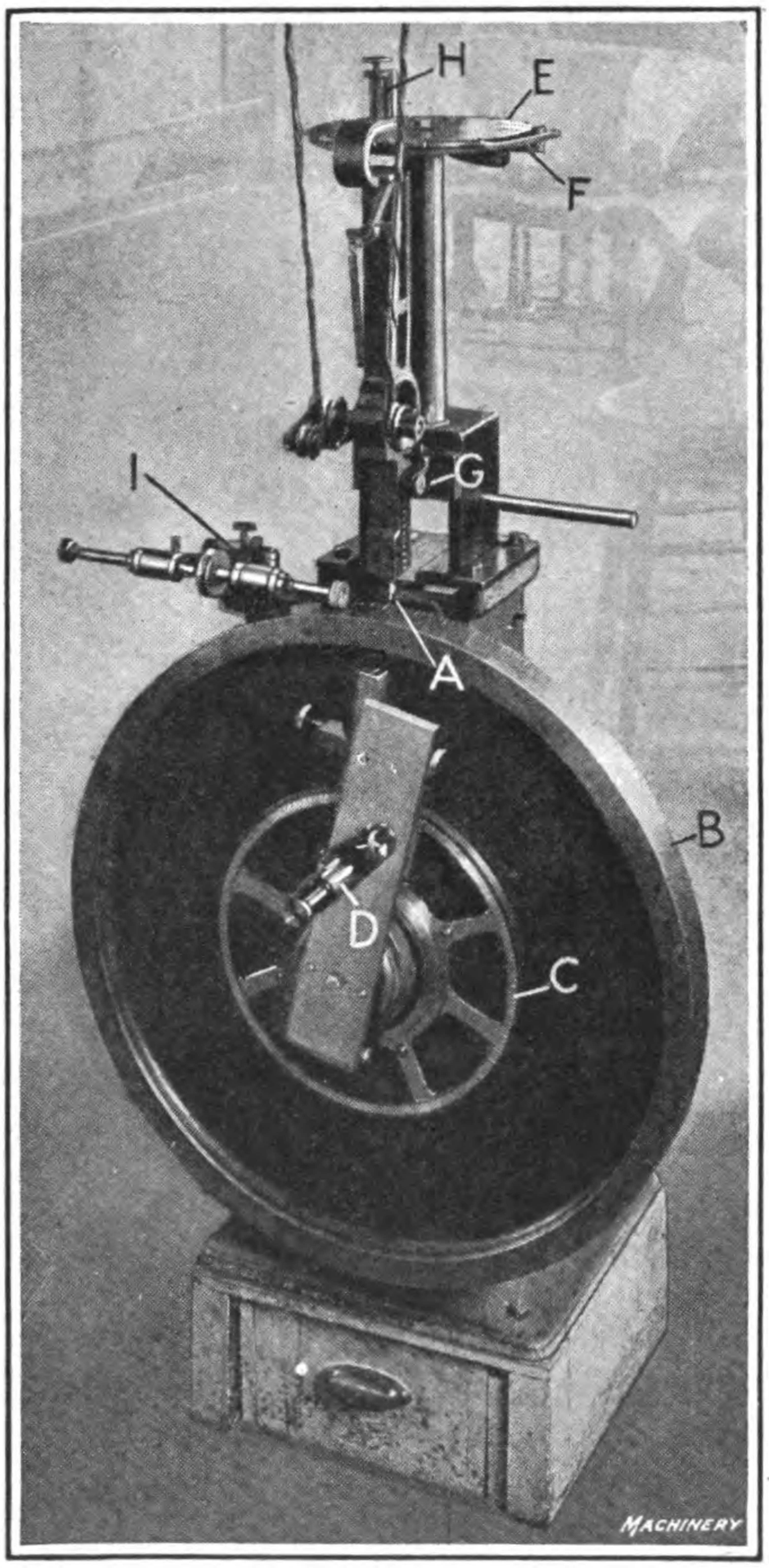


Fig. 7. Simple Design of Circular Graduating Machine

Circle Dividing Machine. William Gaertner & Co., Inc., 5345 Lake Park Ave., Chicago, Ill., builds many astronomical instruments, and for graduating the circular dials required in this work, use is made of the special machine shown in Fig. 7. A variety of work can be handled with this equipment; the illustration shows the machine graduating the declination circle for a large telescope. On this type of graduat- machine the lines are cut by a revolving tool *A*, and the method of operating the machine is as follows: Work *B* is supported on an arbor in such a way that it is free to revolve but may be secured in any desired position by tightening a quick-acting clamp. Fastened to the work there is a "master circle" *C* on which are the same graduations that it is required to cut in the periphery of work *B*. A bracket secured to the end of the arbor that supports work *B* is fitted with a telescope *D*, in the field of which is placed a cross-hair that may be lined up with any desired graduation on master circle *C*. In operating the machine, the first line is cut, after which the clamp is released and work *B* is rotated until the next line on master circle *C* comes into coincidence with the cross-hair in telescope *D*; the clamp is then tightened to secure the work in this position ready for the next line to be graduated. This process is continued until the lines have been cut all the way around the periphery of the work.

Varying Lengths of Graduation Lines. As in the case of most graduating operations, it is necessary in handling this work to cut lines of varying lengths, and on the machine shown in Fig. 7, this is accomplished by having a master plate *E* on which are cut lines of varying lengths, which correspond with those to be graduated on the work. The periphery of this plate has notches cut in it to receive index plunger *F*, and each time the work is indexed by means of master circle *C* and telescope *D*, plate *E* is also rotated to bring plunger *F* into the next notch, thus locating a line of the proper length under the stylus *H*. Engraving tool *A* is mounted at the lower end of a vertical arm, which is pivoted at *G*, the location of this pivot being adjustable so that various ratios may be obtained between the length of lines cut on work *B* and the length of lines in master plate *E*, over which stylus *H* is moved. It will be apparent that the indexing of plate *E* is for the purpose of bringing successive lines on this plate into position for engagement by stylus *H*, thus enabling a sequence of lines of the desired lengths to be cut on the work. At *I* is shown a grinding attachment for sharpening engraving tool *A* when necessary.

Multiple Type of Graduating Machine. Graduating machines of the pantograph type are extensively used wherever graduating must be done on a commercial basis. Some of these machines are designed for graduating or engraving one part at a time, whereas others are intended for multiple graduation. A machine of the multiple type,

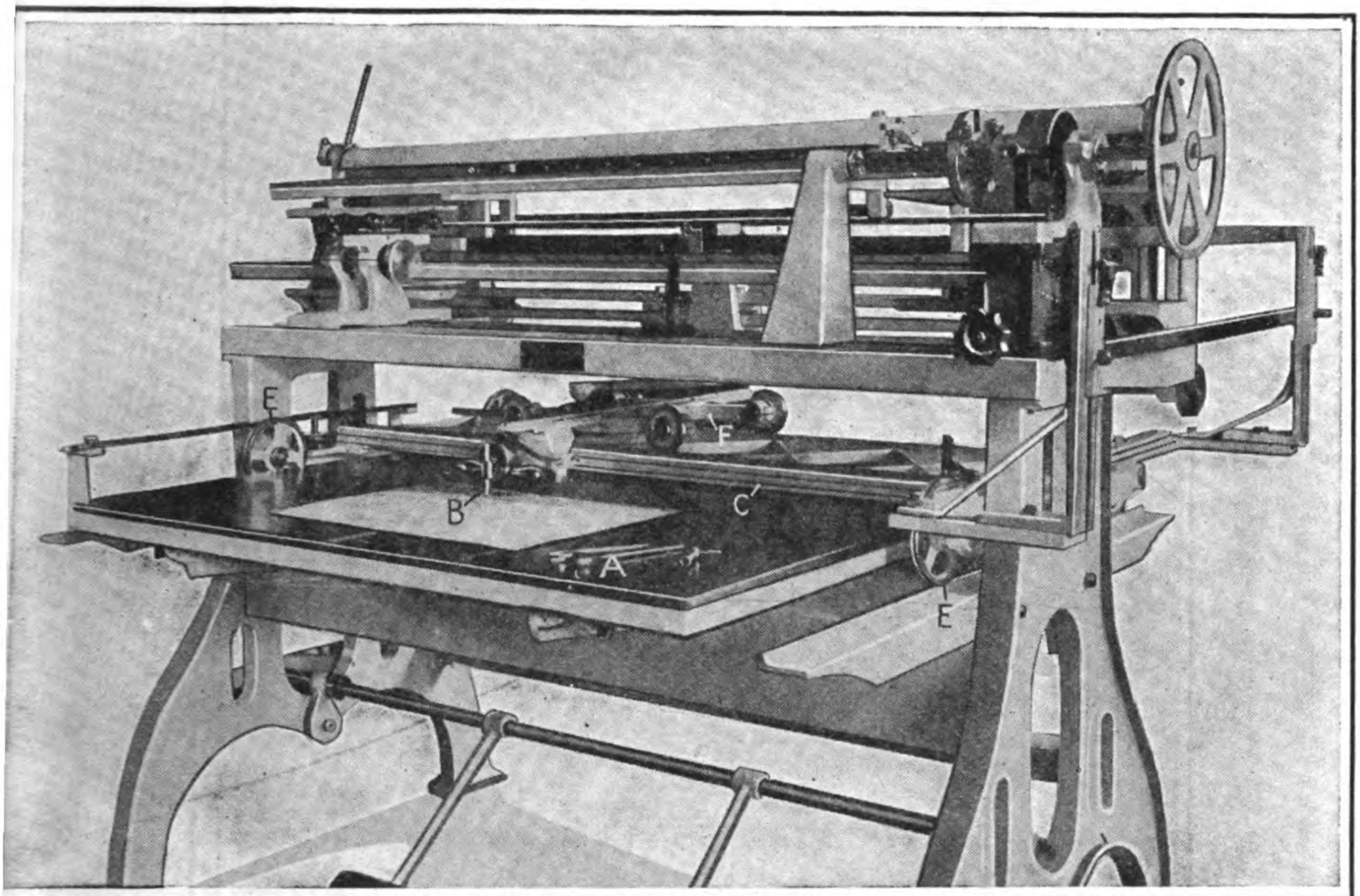


Fig. 8. Hand-operated Multiple Graduating Machine

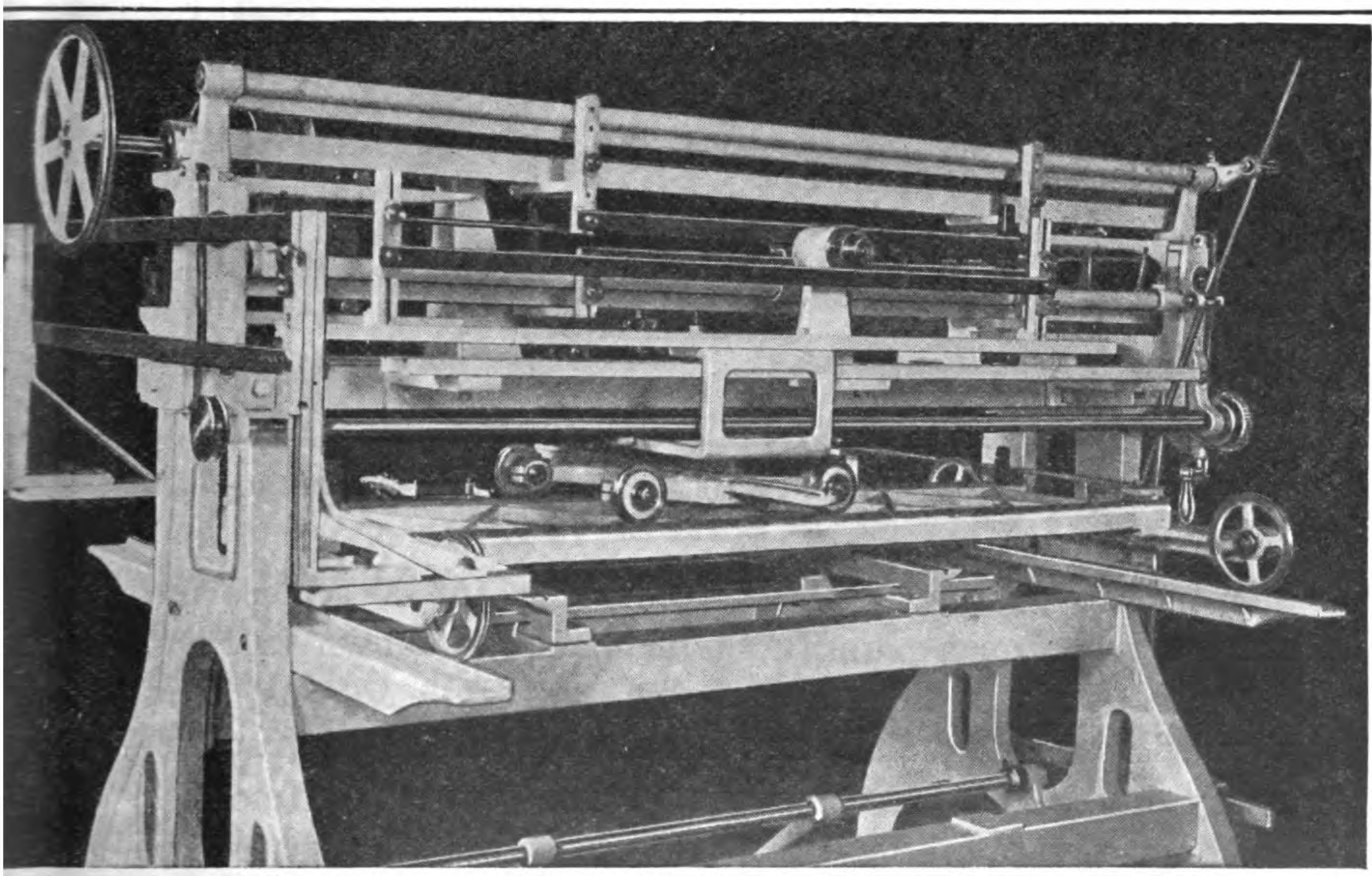


Fig. 9. Opposite Side of Graduating Machine shown in Fig. 8

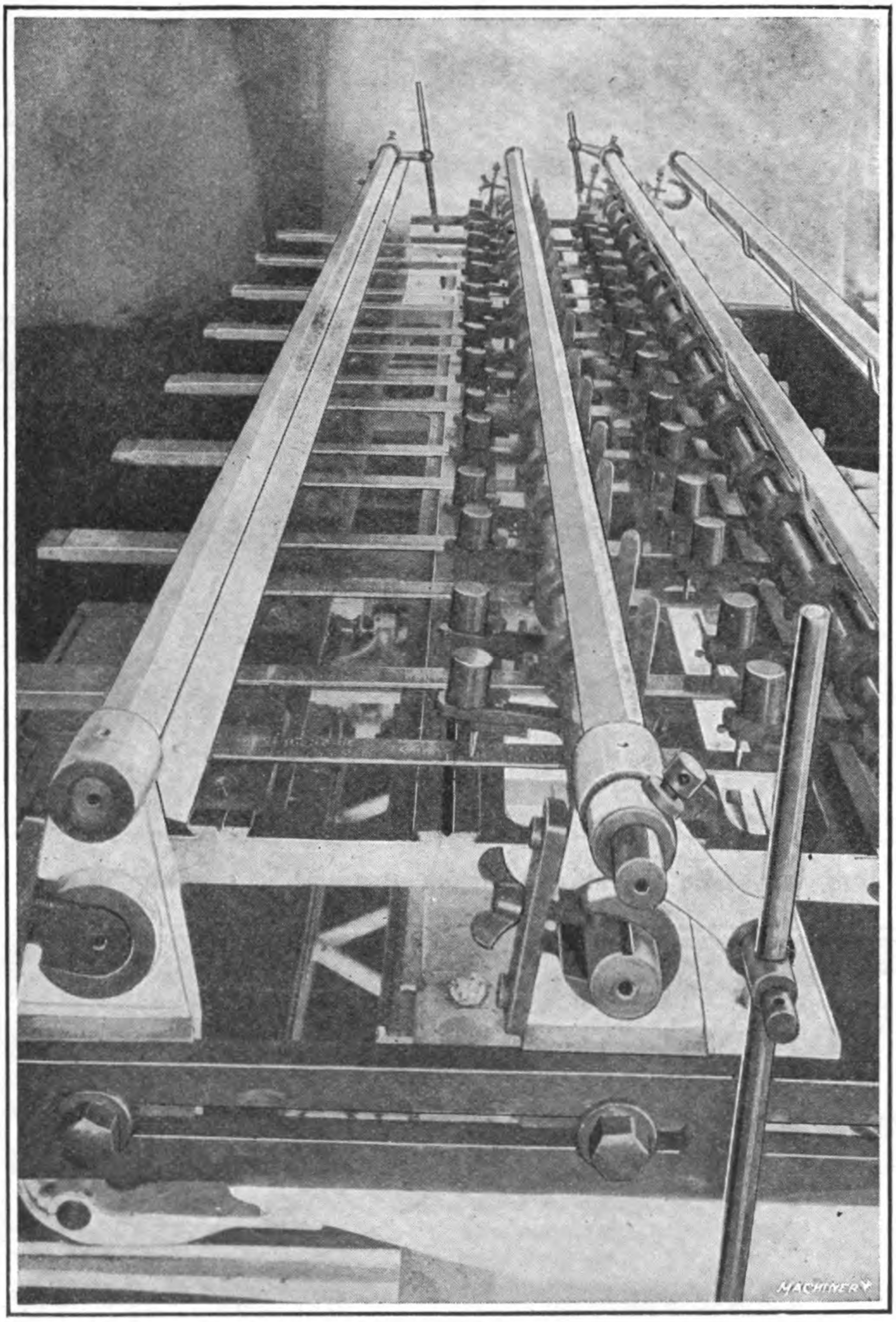


Fig. 10. Close View of Work-holders and Graduating Tools on Hope Machine

adapted for graduating steel rules, machinists' scales, and similar tools, on a manufacturing basis, is shown in Figs. 8 and 9. This machine is built by John Hope & Sons, Elmwood, Providence, R. I., and is so arranged as to graduate many duplicate scales or other parts at the same time.

A master scale or pattern is first made as accurately as possible and to an enlarged scale. The machine, with its pantograph reducing mechanism, is then used to reproduce this master scale on the work. The pattern is attached to table *A* and, as the lines or figures, or whatever outline or design is to be reproduced, are followed by the tracer or pointer *B*, the movements are transmitted through the pantograph mechanism to the parts to be graduated. The tools do not cut the lines into the metal, but mark through a thin coating of acid-resisting material that has been previously spread over the surface of the work. When all the lines required have been cut into the resist, the work

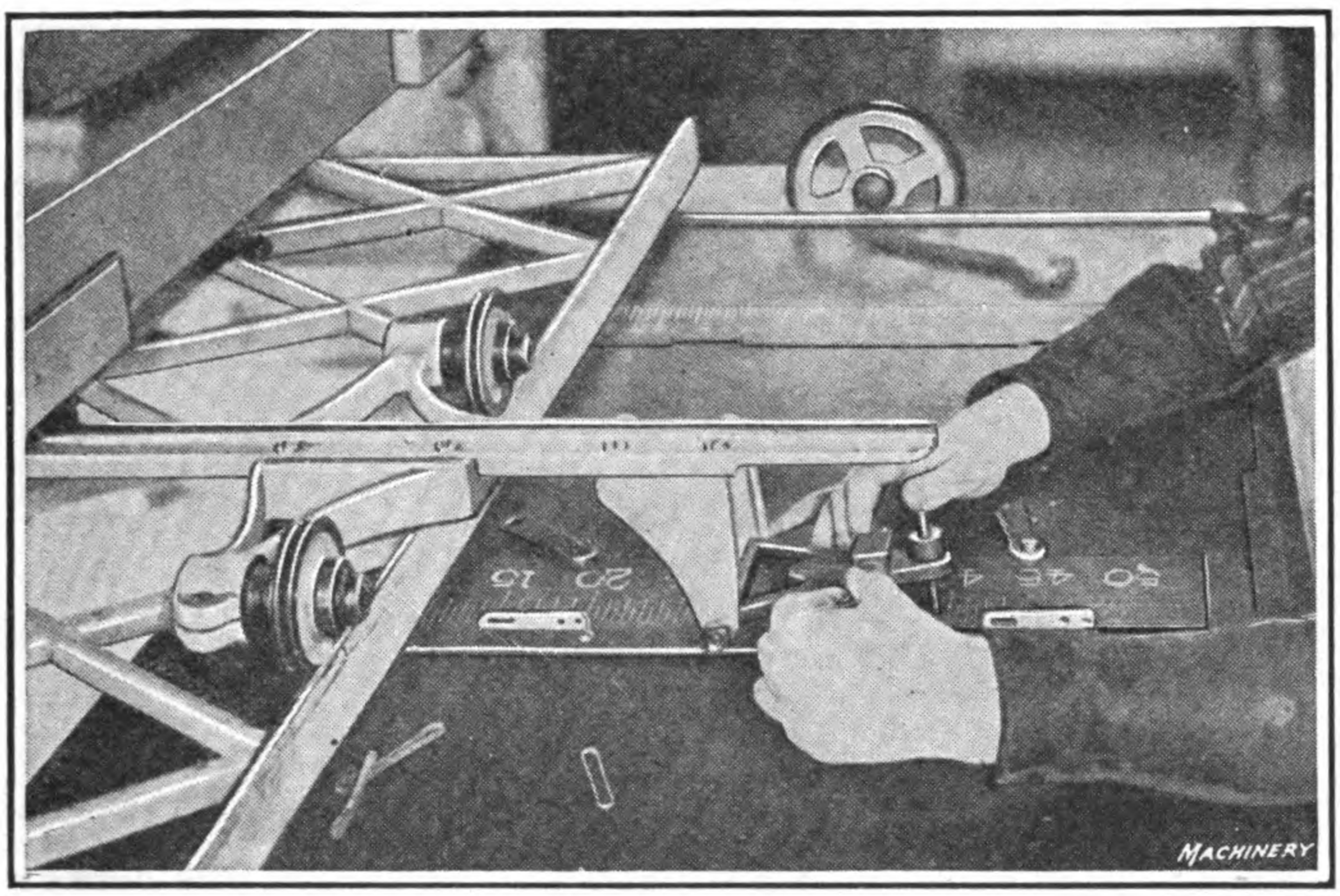


Fig. 11. Close View of "Master" or "Copy," illustrating Method of guiding Stylus over Graduated Marks

is removed and a suitable etching acid applied which eats into the metal and forms lines wherever the resist has been removed by the marking tools. Ordinarily, these tools or points are diamond chips, set into steel holders. The diamond chips last two or three years before repointing is necessary. Some concerns use hardened steel marking points.

Graduating Steel Scales. When graduating steel scales on this machine, forty-eight six-inch scales may be operated on simultaneously, in which case a corresponding number of diamond points is employed. There are four work-holders, each of which has a capacity for holding six feet of work, that is, twelve six-inch scales. When the machine is in operation, movement of the tracer point *B* is transmitted to all the marking points, which are located at the top of the machine. The tracer point may be moved in any direction for following straight lines, figures, or any irregular design. When marking ordinary graduation lines on scales, the tracer (which is guided by the operator) is made to traverse each line on a master scale clamped to table *A*. The lateral movements of the tracer cause the main carriage *C*, which is mounted on wheels *E*, to move

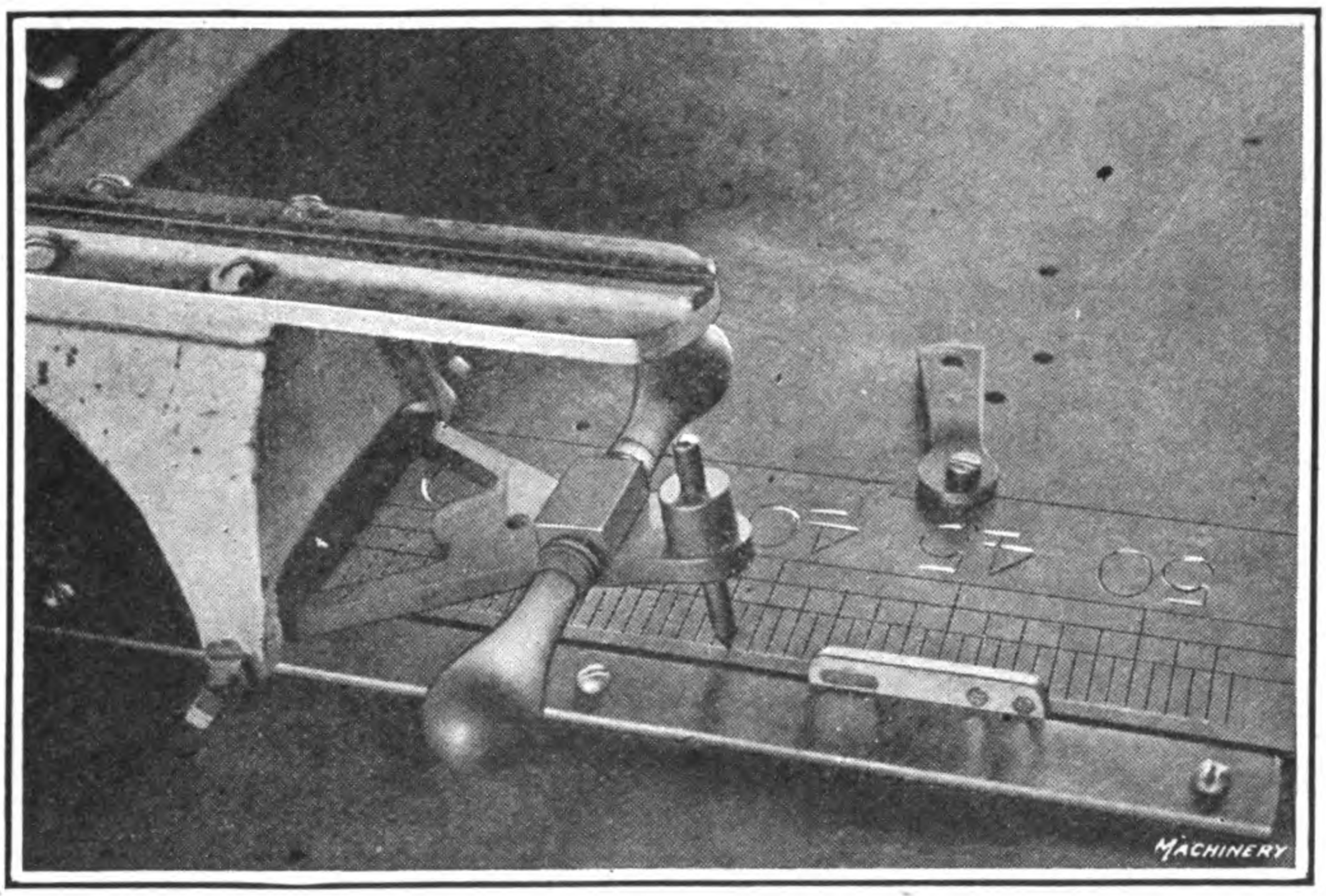


Fig. 12. View of Master Copy, Stylus and Handles for operating Stylus

along the track shown, whereas the longitudinal movements shift the smaller carriage *F* along the track formed on carriage *C*. Every movement of the tracer is transmitted through the pantograph mechanism to the work-table which holds the scales or other parts to be graduated. The pantograph mechanism may be adjusted to reproduce the pattern on any scale varying, on this particular machine, from one-third to one-twentieth the size of the pattern or copy. A foot-treadle is used to bring the diamonds into contact with the work. An idea of the rate of production will be gathered from the fact that girls operating these machines

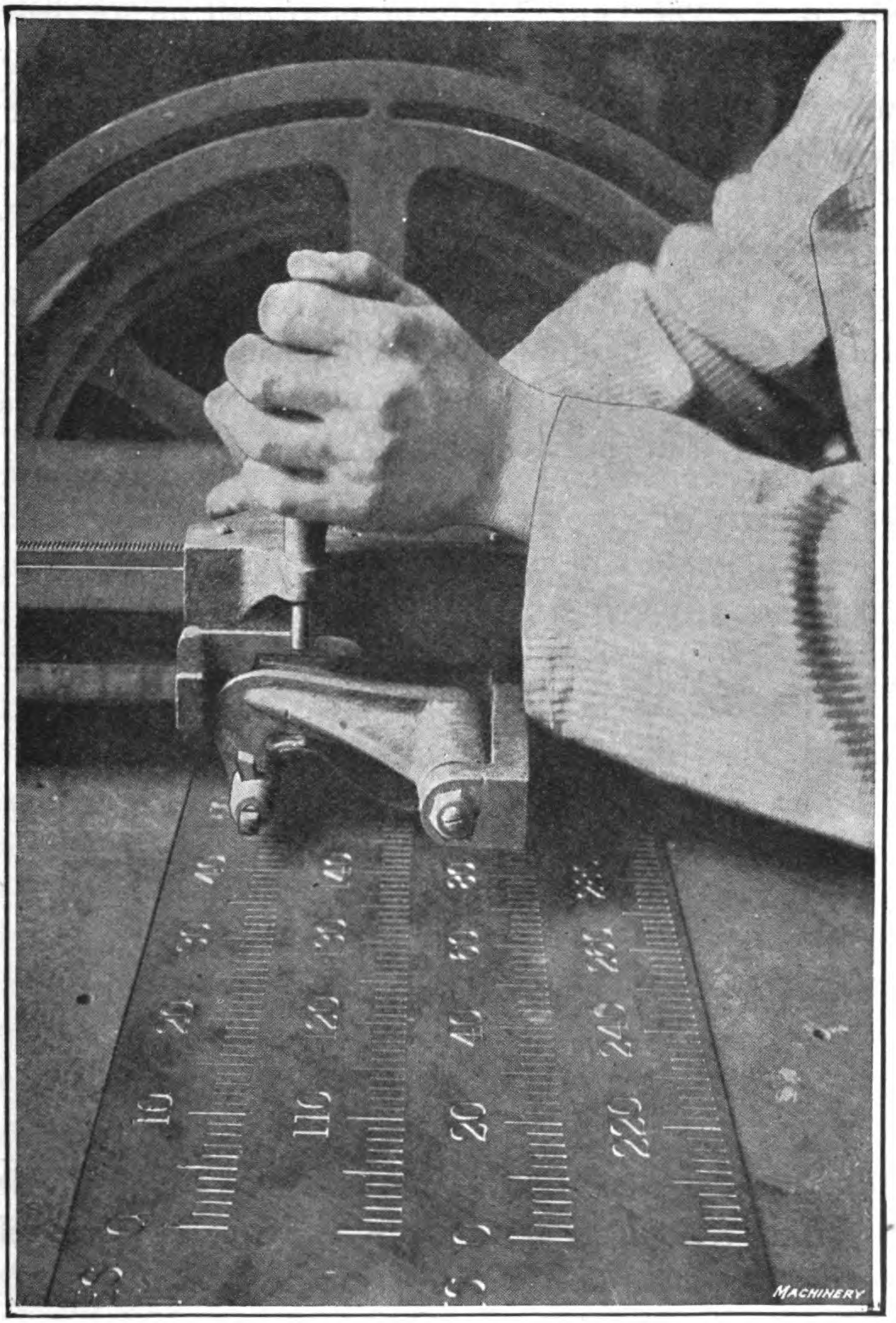


Fig. 13. Machine used for making Master Scale

in the plant of the Sawyer Tool Mfg. Co., Ashburnham, Mass., have each marked 200 feet of scales per day.

The Master Scale or Pattern. The master scale is made on a special machine, shown in Fig. 13, consisting principally of a precision lead-screw, a large dividing wheel for accurately spacing the division lines, and a tool for cutting these lines. The figures may be engraved on an ordinary engraving machine or they may be cut into the master by hand. The master scale is not always in the form of an enlarged copy of the scale to be reproduced. A special design used for graduating steel rules is shown in Fig. 14. It is 12 inches long and has four sides (see end view), on which are the different graduations required. This cross-shaped master is mounted in bearings so that any side may be turned to the upper or operating position, thus locating the face of that particular side just a little above the

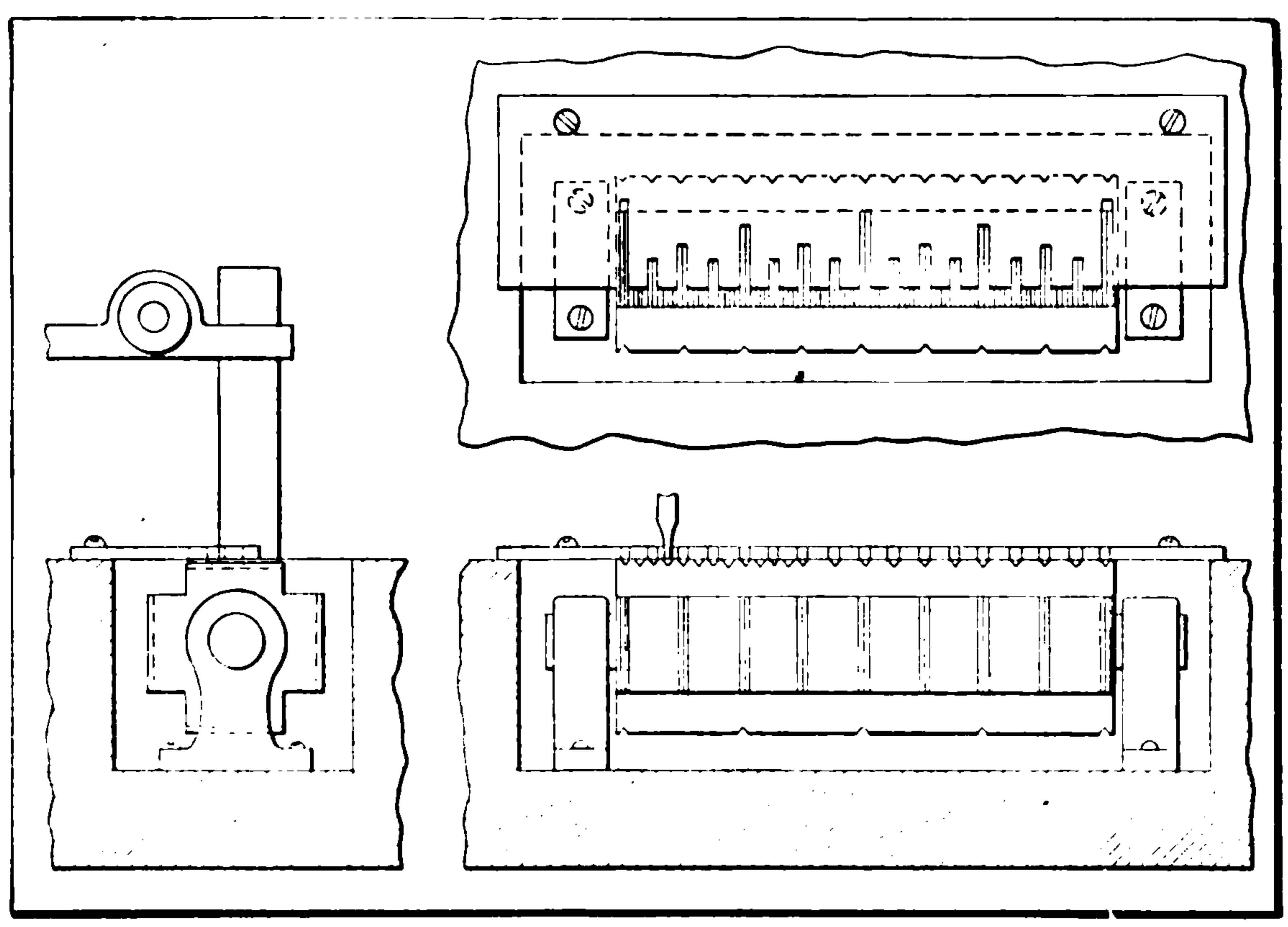


Fig. 14. Type of Master Pattern used for graduating Scales on Machine shown in Figs. 8 and 9

graduating machine table. The tracer of the machine is not pointed, but is chisel shaped, to correspond with the V-shaped grooves in the master. The length of the various division lines is regulated by a fixed plate or gage above the master, which has slots that limit the movement of the tracer. The space between the grooves on the master is much wider than on the graduated scales, the necessary reduction being obtained by the pantograph mechanism. The master is twelve inches long, but it is provided only with the graduations corresponding to a length of one inch on the scale. After marking the graduation lines for a length of one inch, the diamonds on the graduating machine are set in alignment for graduating the next successive inch division. This master is used on a machine of the type shown in Figs. 8 and 9, forty-eight steel rules being graduated simultaneously. These rules have one-half inch of excess metal at each end, which is cut off after graduating, this excess length enabling the rules to be held readily. The marking of the figures into the resist involves a separate operation.

Increasing Visibility of Graduation Lines. In order to secure a greater contrast between the graduation lines and the background, the lines are sometimes filled with a pigment, such as black sealing wax or white lead, depending upon whether the background is light or dark. In some cases the lines are filled with block tin, which is melted into them. The surface is then polished so that the lines or figures are in clear contrast with the background. A mixture of paraffin and lampblack is also used on light work. One method of treating graduation lines which have been cut into black vulcanized rubber, by means of a machine of the Gorton type having a rapidly revolving cutter, is as follows: The lines formed by the engraving machine are filled with a paste composed of zinc oxide mixed with enough paraffin to give it a plastic consistency. A small amount of this paste is rubbed over the graduation marks, and the surplus is wiped off with a cloth. This paste is very hard and durable when dry, and the white lines on the black rubber background are readily seen.

Graduating by Impression Method. When large numbers of duplicate parts require to be graduated and extreme accuracy is not necessary, the lines are sometimes formed by the use of steel stamps for flat work, or rolls for circular parts. The stamp or roll, as the case may be, has the lines and figures formed on it and is hardened so that, when the graduating tool is pressed against the work, the lines are reproduced. Fig. 15 shows a special tool for graduating index collars such as are used on the feed-screws of machine tools. The tapering arbor *A* is fitted into the lathe spindle and holds the part to be graduated at its outer end. A gear forming part of this arbor meshes with gear *B*, which is keyed to stud *C*. This stud is mounted in a holder *D* that is fastened in the toolpost of the lathe. The graduating roll is keyed to the stud *C* and is forced against the work so that the graduation lines and

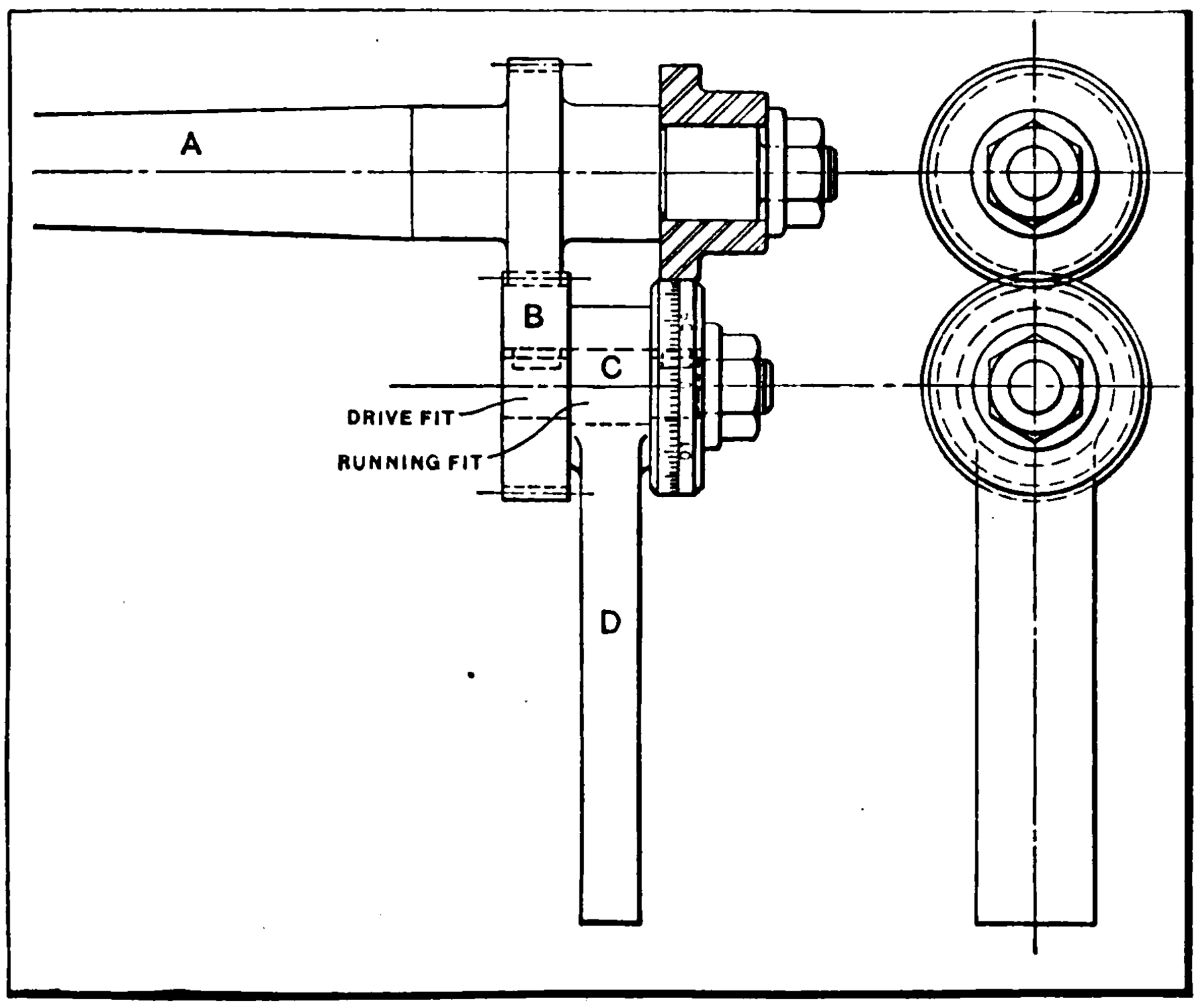


Fig. 15. Tool for graduating Index Collars by Impression Method

figures on it are reproduced on the index collar as the two revolve together. The geared drive is preferable to a friction drive between the graduating roll and the work-arbor, because it is positive and prevents any shifting of the work relative to the graduating roll.

Machine for Graduating Micrometer Dials. In building Conradson engine lathes, the Phoenix Mfg. Co., of Eau Claire, Wis., uses a special bench machine shown in Fig. 16 for graduating micrometer dials. It will be seen that this machine is of the type in which impressions are made by a hardened roller *A*, which is forced into work *B* without removing any metal. This is a hand-operated machine, which is actuated by turning handwheel *C* mounted at the end of a cross-shaft, on the opposite end of which there is a pinion that meshes with gear *D*. In graduating dials, it is necessary to make lines of different lengths; for instance, it may be required to cut four lines of the same length and then a fifth line of greater length. Movement of the slide

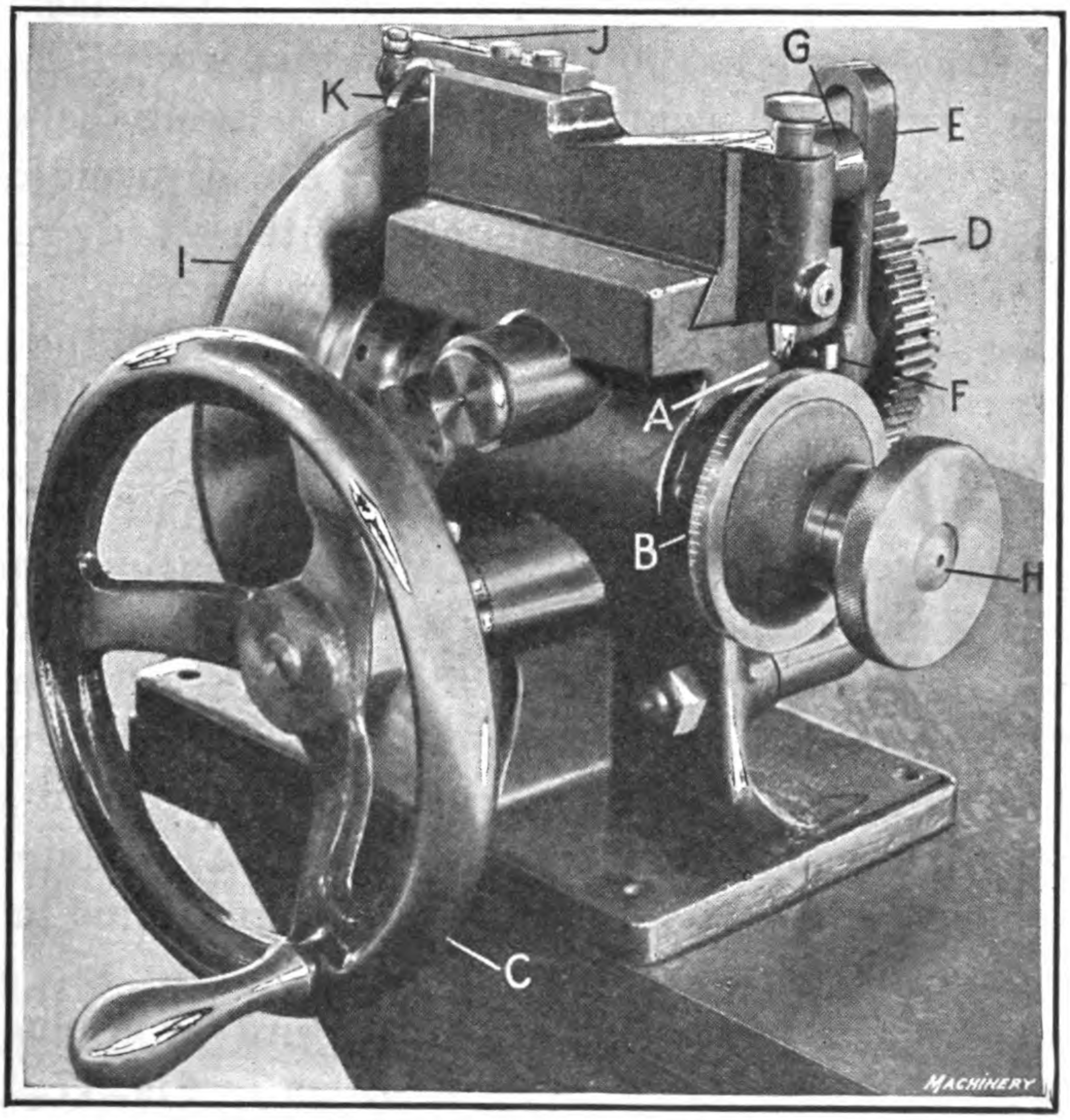


Fig. 16. Special Machine designed for rolling Graduation Marks into Feed Collars used on Conradson Engine Lathes

that carries hardened steel roller *A* is obtained by means of a multiple-lobed cam located inside the rim of gear *D*, which engages with a roller mounted at the lower end of lever *E*. This lever has its fulcrum at *F*, and makes connection with the slide by means of a pin extending into slot *G*, the roller that engages the multiple cam being located at the opposite side of fulcrum *F* from the pin that extends into the slot at the upper end of the lever.

As gear *D* revolves, the roller at the lower end of lever *E* rides over successive lobes on the cam inside the rim of gear *D*, and as each lobe is passed, the upper end of lever *E* is rocked forward, which results in feeding the hardened steel graduating roller *A* over the surface of work *B*. The length of stroke of roller *A* is regulated by the height of the different cam lobes, which provides for marking lines of the desired lengths. It will be seen that work *B* is carried on a horizontal mandrel *H*, and for indexing the work, there is a ratchet wheel *I* at the rear end of mandrel *H*, which has the same number of teeth as there are graduations to be cut in the complete circle on the work. To provide for automatic indexing, a cam *J* is secured to the back of the slide that carries marking roller *A*, and this cam engages with a roller mounted on the pivoted bracket that supports pawl *K*. During each return stroke of the ram, cam *J* moves pawl *K* forward, thereby advancing ratchet wheel *I* through one tooth space, which corresponds to one division on the work. Then, as the cam moves forward to cut the next graduation mark, cam *J* allows a spring to draw pawl *K* back so that it drops into engagement with the next tooth on ratchet wheel *I*. It will be of interest to note that feed dials have been completely graduated in this way in a little less than two minutes.

Use of Stamp for Graduating. A fixture for graduating the sleeves of drilling machines is shown in Fig. 17. The casting *A* of this fixture is machined to fit the sleeve, as shown. The latter has a spline in it in which the block *B* is held by screw *C* to retain the sleeve in the correct position. The hardened steel clamp *D* (see also enlarged view at *F*) is made to graduate the sleeve for a length of one inch, the graduations being to sixteenths of an inch. The stamp *D* is held in a slot in the fixture by means of a cap *G*. When a sleeve is to be graduated, it is placed in the fixture with one end against the stop *H*. The stamp is then given a blow with a hammer, after which the spring plunger *I* is withdrawn, thus allowing rod *J* and stop *H* to be shifted to the next successive hole, which locates the stamp for graduating the next inch division. This operation of shifting the sleeve and the stop is repeated until the sleeve has been graduated to the required length.

Graduating with Milling Machine. A milling machine equipped with a spiral head is sometimes used for graduating verniers, flat scales, and other parts requiring odd fractional divisions or graduations. The spiral-head spindle should be geared to the table feed-screw so that a longi-

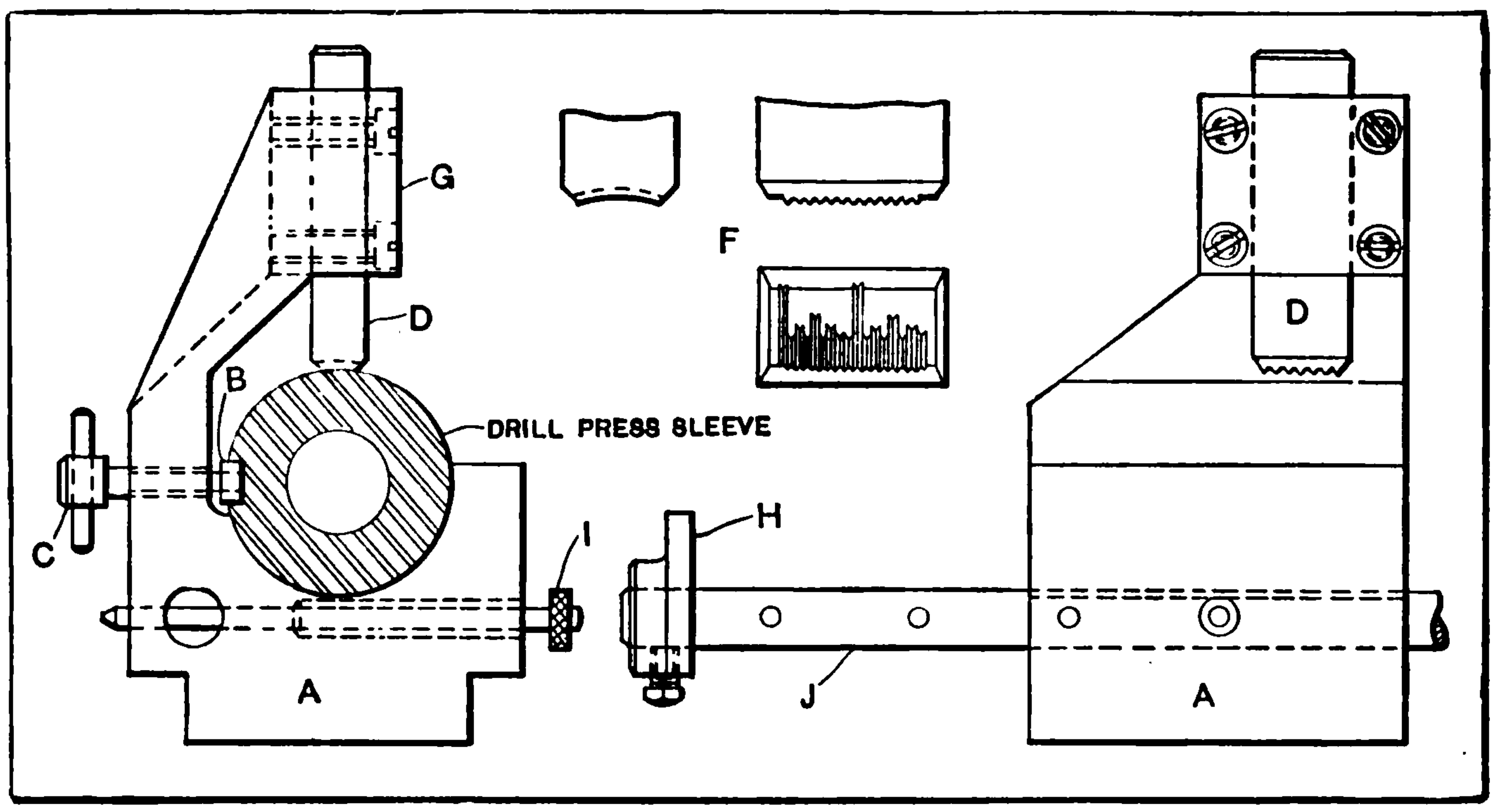


Fig. 17. Fixture for graduating Drilling Machine Sleeves with a Stamp

tudinal movement of the table is secured by turning the indexing crank. When using a Brown & Sharpe machine, the gear for the spiral head is mounted on the differential index-center inserted in the main spiral-head spindle. By varying the indexing movement, graduations can be spaced with considerable accuracy. The graduation lines are cut by a sharp-pointed tool held either in a fly-cutter arbor mounted in the spindle, or between the collars of a regular milling cutter arbor. The lines are drawn by feeding the table laterally by hand, and the lengths of the lines representing different divisions and subdivisions can be varied by noting the graduations on the cross-feed screw. The gearing between the spiral-head spindle and feed-screw should be equal or of such a ratio that the feed-screw and spindle rotate at the same speed. Assume that the lead of the feed-screw thread is 0.25 inch and that 40 turns are required for one revolution of the spiral-head spindle; then one turn of the index-crank will cause the table to move longitudinally a distance equal to one-fortieth of 0.25, or 0.00625 inch. ($1/40 \times 25/100 = 0.00625$.) Suppose graduation lines 0.03125 or 1/32 inch apart were required on a scale. Then the number of turns of the index-crank for moving the table 0.03125 inch equals $0.03125 \div 0.00625 = 5$ turns. If the divisions on a vernier reading to thousandths

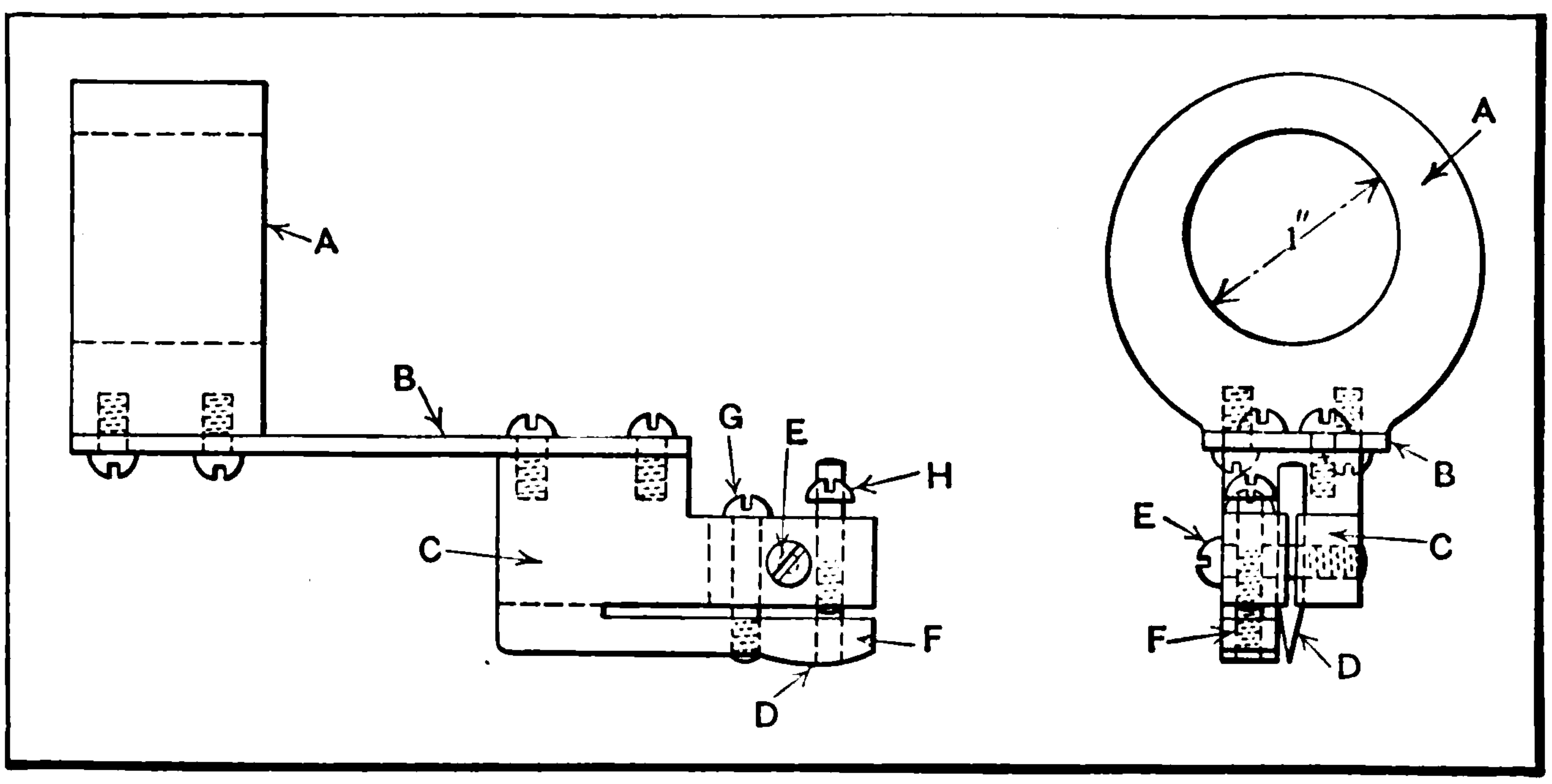


Fig. 18. Graduating Tool for cutting Fine Lines of Uniform Depth

of an inch were to be 0.024 inch apart, the indexing movement would equal $0.024 \div 0.00625 = 3.84$ turns. This fractional movement of 0.84 turn can be obtained within very close limits by indexing 26 holes in the 31-hole circle; thus, three complete turns will move the work $0.00625 \times 3 = 0.01875$ inch, and 26/31 turn will give a longitudinal movement equal to 0.00524 + ; therefore, a movement of 3 26/31 turns $= 0.01875 + 0.00524 = 0.02399$ inch, which is 0.00001 inch less than the required amount.

Graduating Tool for Fine Lines. The special form of tool shown in Fig. 18 has been used successfully for cutting fine lines of uniform depth when graduating with the milling machine. This tool is held on a regular cutter-arbor by means of the collar *A*, and, when graduating the spindle of the machine is locked to prevent any rotary movement. The lines are cut by a sharp-pointed tool *D* made of drill rod. This tool is held in block *C* by screw *E*, the block being split as shown. The lower part of block *C* is provided with a shoe *F* which may be adjusted by screws *G* and *H*. This shoe rests upon the surface of the part to be graduated and regulates the depth of the graduation lines. When using this tool, the work-table is adjusted vertically so that the tool is sprung upward slightly or until the flat spring *B* gives sufficient pressure to overcome the resistance of the cut. As the tool is always in contact with the work, the lines are cut to a uniform depth, even though the surface being graduated is not perfectly flat. This tool was designed for graduating the scales on chronographs. The work was held in a lengthwise position on the table, and the lateral movements for controlling the length of the different graduation lines were regulated by inserting small parallel strips of different thicknesses between stops on the cross-slide, which were set for the length of the longest line.

CHAPTER II

ENGRAVING MACHINES AND METHODS

It is generally understood that graduating machines are used for cutting the division lines on various forms of scales, and that engraving machines are used for cutting letters, figures and designs in the work. These two classes of machines are naturally associated with each other, because there are a number of graduating machines on which no provision is made for cutting figures to indicate the value of scale graduations or the manufacturer's name, trademark, etc. As a matter of fact, the distinction between these two types of machines is rather fine, because many engraving machines can be used for graduating when suitable provision is made for handling this class of work. Further discussion of this subject will be continued later.

Types of Engraving Machines. Engraving machines are designed to reproduce the form of a pattern or model on the part to be engraved, by means of a mechanism which transmits the movement of a tracing point to a suitable cutting tool. In the operation of the machine, the tracing point is made to follow the pattern or model, usually by guiding it with the hand. There are two general types of engraving machines. On one type the tool does not revolve, but is drawn across the work so that it operates the same as a planing tool. The angular position of the graver or tool may be varied to secure different effects, and the tool-holder may also be turned on some machines so that the graver will be kept facing the changing direction of the cut, but the tool does not revolve continuously.

Engraving machines may be further classified according to the form of mechanism utilized for reproducing the pattern or model on the engraved part. Many of the types intended more particularly for engraving letters or ornate designs on nameplates, dies, silverware, etc., have a pantograph mechanism for reproducing the pattern or model on a reduced scale. Other machines of the reducing type, or those using a model that is considerably larger than the design or form to be engraved, are so arranged that the

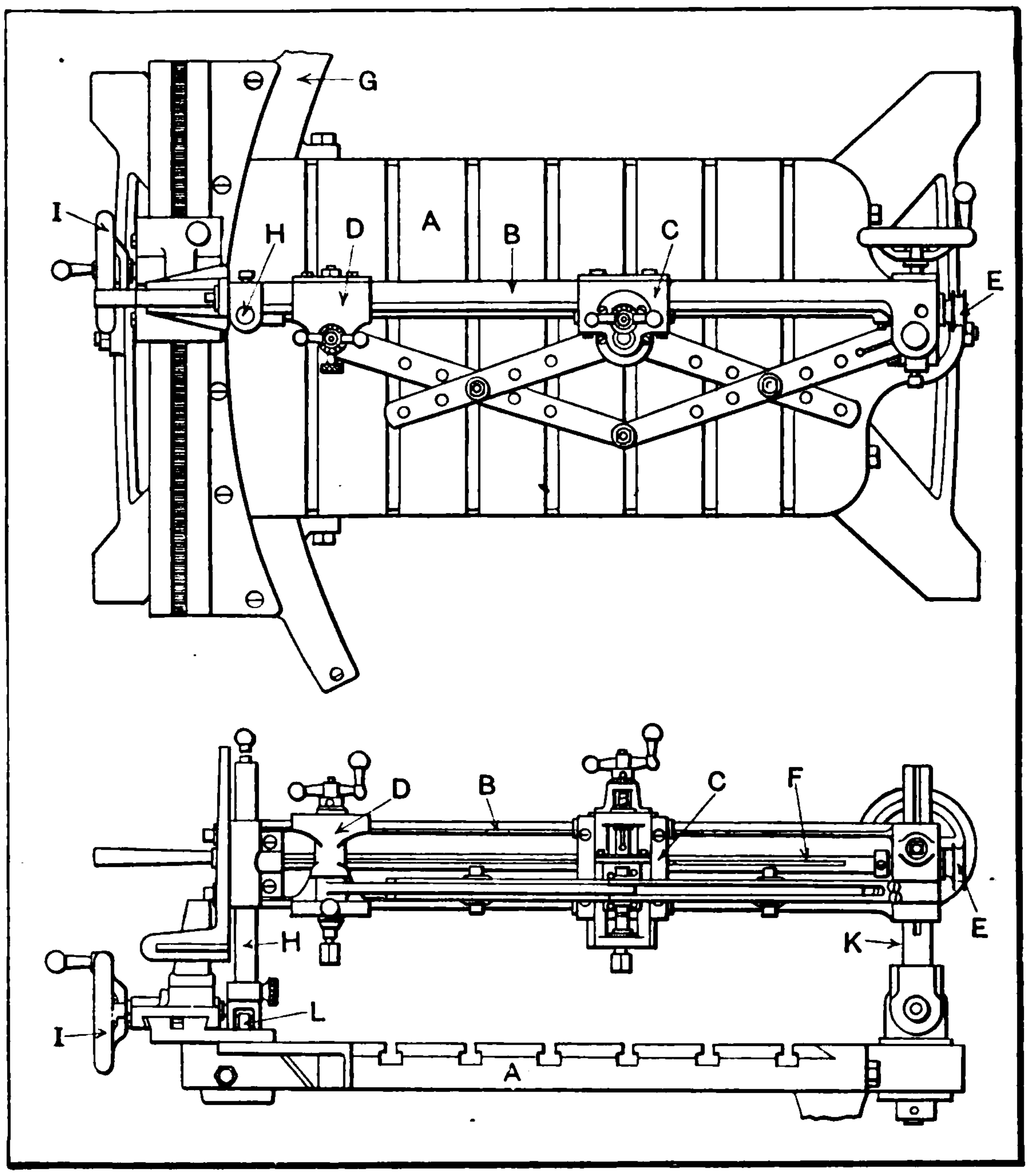


Fig. 1. Engraving and Die-sinking Machine of Pantograph Type

necessary reduction between the movement of the tracing point which bears against the pattern and the tool or cutter is obtained by simply attaching the tracer and cutter-head to a lever at distances from the pivot of the lever proportional to the reduction required between the pattern and engraved part. Another type of engraving machine does not have a reducing mechanism, but the tracing point bears against a model corresponding in size to the impression to be engraved, and this tracing point guides the cutting tool by a direct connection with the cutter-spindle, or the member in which it is mounted.

Engraving Machine of Pantograph Type. While many engraving machines have the same type of mechanism for causing the cutter to reproduce the movement of the tracing point on a smaller scale, the general design of different machines varies considerably. A machine built by an English manufacturer (Thomas Auty & Co.) is illustrated in part by the front elevation and plan view, Fig. 1. This type of machine is used for a variety of die-cutting work, as well as for general engraving operations. The desired form is reproduced from an enlarged former or model, by means of a pantograph mechanism, shown more clearly in the plan view. The part to be engraved is clamped to table *A* under the head *C*. The head carries a milling cutter which moves in the same direction as the tracing pin in head *D*, only on a reduced scale, the reduction depending upon the adjustment of the pantograph mechanism. The arm *B* which extends across the work-table is pivoted so that it can be traversed in a horizontal plane around the axis of the vertical stud *K*. This horizontal arm *B* is supported at its outer end by a roller *L* on the end of rod *H*, the roller traveling along the circular path *G* of the machine table. The horizontal movement of arm *B* may be effected either directly by hand or mechanically through a rack and pinion by turning handwheel *I*. The stud *K*, upon which arm *B* is pivoted, is connected to the table by a joint which permits the arm to rise and fall in a vertical plane, so as to accommodate itself to any irregular surfaces on the work. By traversing the tracing head *D* longitudinally along the arm, the tracing pin is moved in or out as the arm swings horizontally, in order to follow the outline of the former or pattern. Any movement that is given to the tracing head *D* is reproduced by the cutter-head *C* on a reduced scale.

The cutter-spindle is driven by a shaft *F* which carries a belt pulley *E*. Motion is transmitted from the shaft *F* to the cutter-spindle, through helical gearing in the cutter-slide. The arm *B* is secured to stud *K* by means of a set-screw, and the height of the arm may be varied according to the height of the work being operated upon. There is a spring-support on the end of rod *H*, which takes the

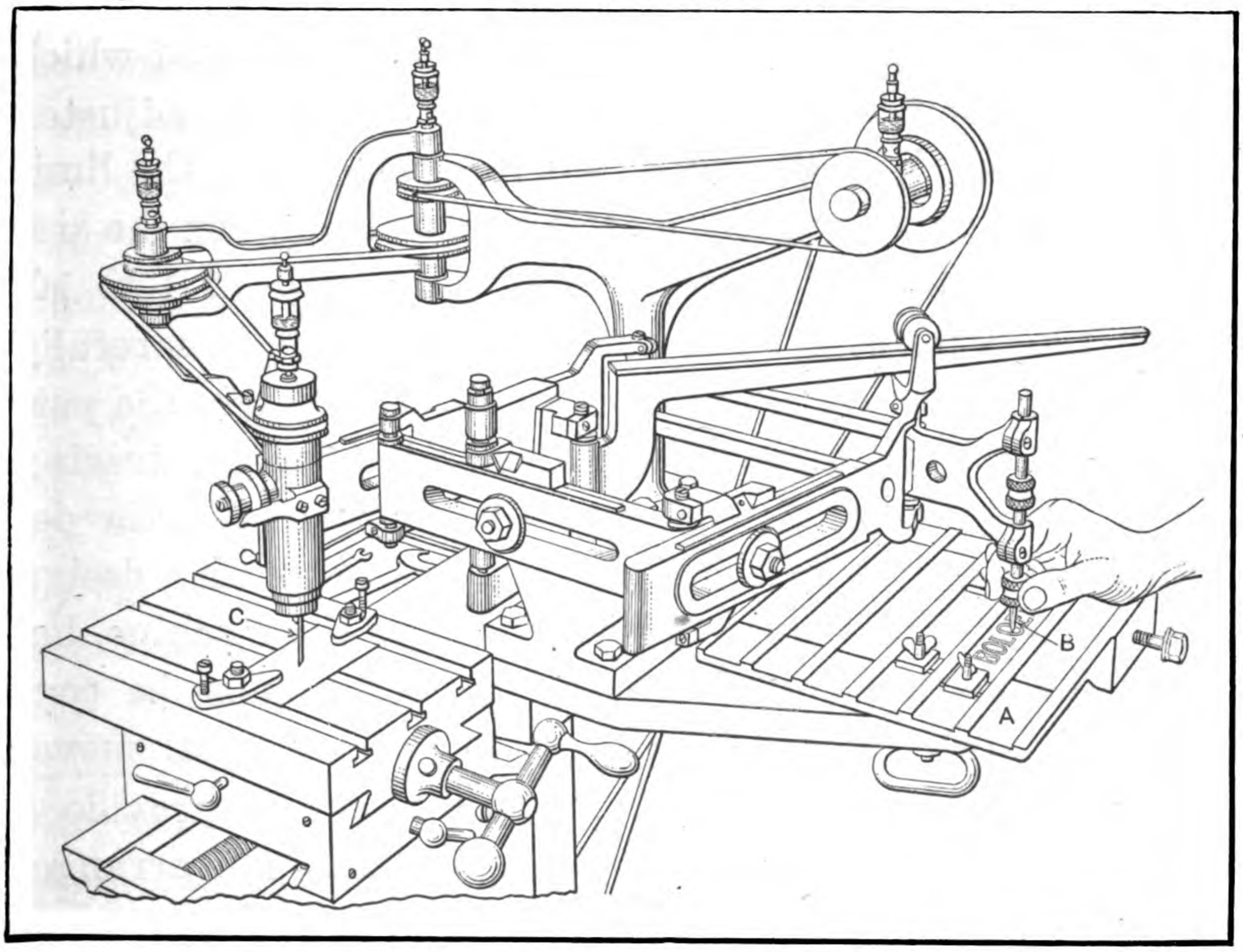


Fig. 2. Pantograph Mechanism provided with Graduated Scale Adjustment

weight of the arm when vertical movements are required. A thumb-screw is provided for preventing the spring from acting when vertical movements are not required.

Engraving Machine Having Graduated Pantograph. Another engraving machine which operates on the pantograph principle, but differs in design from the one previously described, is shown in Fig. 2, which illustrates the pantograph mechanism and the method of rotating the cutter-spindle. This machine is used for engraving nameplates, trademarks, letters, numbers, etc., on steel stamps, dies and other products. A pattern of the required design is placed in a slot in the pattern table *A*, where it is clamped in position. At one end of the pantograph, there is a tracing or guiding point *B*, which is made to follow the pattern or letters which are to be reproduced on the work. The engraving tool *C* is carried by a spindle at the opposite end of the pantograph mechanism. Three of the arms on the pantograph are provided with scales by means of which the relation between the lengths of the arms can be adjusted to obtain any desired size of an engraved design, the limit of the machine being from a ratio of 1 to 1 between the size of the work and the pattern, down to a ratio of 1 to 10. When the pattern is to be used repeatedly, it is carefully made and, in the case of letters, these are cut into the pattern plate, thus forming a positive guide for the tracing point. When only a few pieces are to be engraved, the design may be drawn on bristol board, but when such a design is used more care is required in operating the machine, because the movements of the tracing point must be controlled entirely by hand. Owing to the universal movements of the engraving tool, it is necessary to provide a flexible system for driving the cutter-spindle. The arrangement of the belt drive in this particular case is apparent from the illustration.

The engraving tool used on this machine is cylindrical in shape, except at the lower end, where for about 1½ inches a flat is ground so that about one-half of the metal is removed, and a suitable cutting edge is formed on the lower end. Experience has shown that the best results are obtained by having the ground surface of the tool of an elliptical section instead of circular, and this special form is obtained by a grinding attachment used in connection with the machine. By means of this attachment, the motion of the tool is controlled when in contact with the grinding wheel, by means of a cam which forms part of the attachment.

Engraving Cylindrical or Conical Surfaces. When cylindrical or conical surfaces are to be engraved on the machine shown in Fig. 2, an attachment is used which consists principally of a work-holding device that can be tilted to any desired angle, in order to locate the surface in the proper position relative to the engraving tool. This work-holding device can also be rotated or indexed for the accurate spacing of designs to be engraved on different parts of the work. In most cases where engraving is done on cylindrical or conical surfaces, the pattern itself is flat and is clamped to the pattern table in the usual way, to transfer the marking to the work.

Engraving Concave or Convex Surfaces. Either concave or convex surfaces can be engraved on this machine by using an attachment designed for the purpose. When doing work of this kind, it is necessary to have the engraving tool cut to a uniform depth, but the tool must also follow the contour of the work. This means that the tool must be moved vertically as it is traversed in a horizontal direction, the extent of the vertical movement depending upon the curvature of the work. This movement is obtained as follows: The work, instead of being clamped directly to the work-table, is supported by a plate which is mounted upon four studs so that there is a space beneath the plate. On the bottom plate, which is attached to the lower ends of the four supporting studs, there is a master blank which conforms to the curvature on the work. A guide point, connected by a bracket with the cutter-spindle, is in contact with this master blank, so that, as the cutter-spindle is moved horizontally, it also moves vertically, thus causing the tool to cut to a uniform depth. The tracing point is guided by a flat pattern so that the engraved design is not an exact reproduction of the pattern, owing to the curvature of the surface upon which the tool operates. Unless the radius of curvature is very small, however, the error in reproduction is so slight as to be negligible. The work-table of this machine is carried by a knee which may be adjusted vertically along the face of the machine column, and it has, in addition, longitudinal and transverse adjustments.

Gorton Engraving Machine. Another design of engraving machine of the pantograph type which is built by the George Gorton

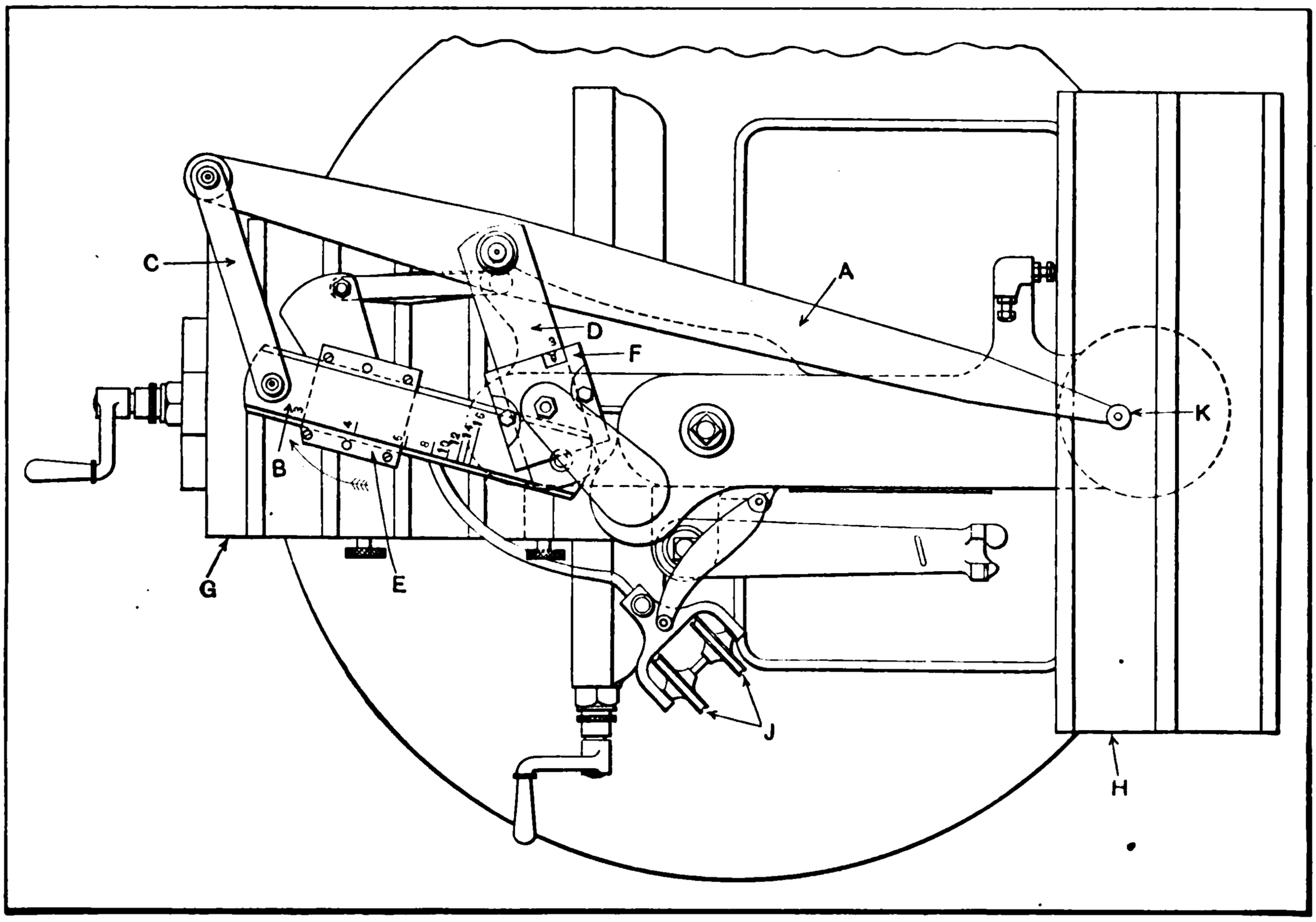


Fig. 3. Pantograph Mechanism on Gorton Engraving Machine

Machine Co., Racine, Wis., is shown in Fig. 3. With this machine reductions in size varying from 3 to 1 to zero may be obtained. In other words, the pantograph mechanism can be adjusted to reduce the size of any particular pattern or copy from one-third down to the point where the movement of the tracer point or stylus does not transmit any motion at all to the engraving tool. The part to be engraved is attached to table *G* which is provided with slots for receiving clamping bolts. This table is mounted upon a knee and can be adjusted vertically and horizontally. The engraving is done by cutters of different shapes which are held either in a chuck or directly in the spindle. The latter method is employed for the larger sizes having tapered shanks.

The cutter-spindle is located below the sliding block *E* and is driven by a small band or belt connecting with an overhead countershaft and passing over the idler pulleys *J* to a pulley on the spindle. For engraving brass, the cutter is rotated at a speed varying from 8000 to 10,000

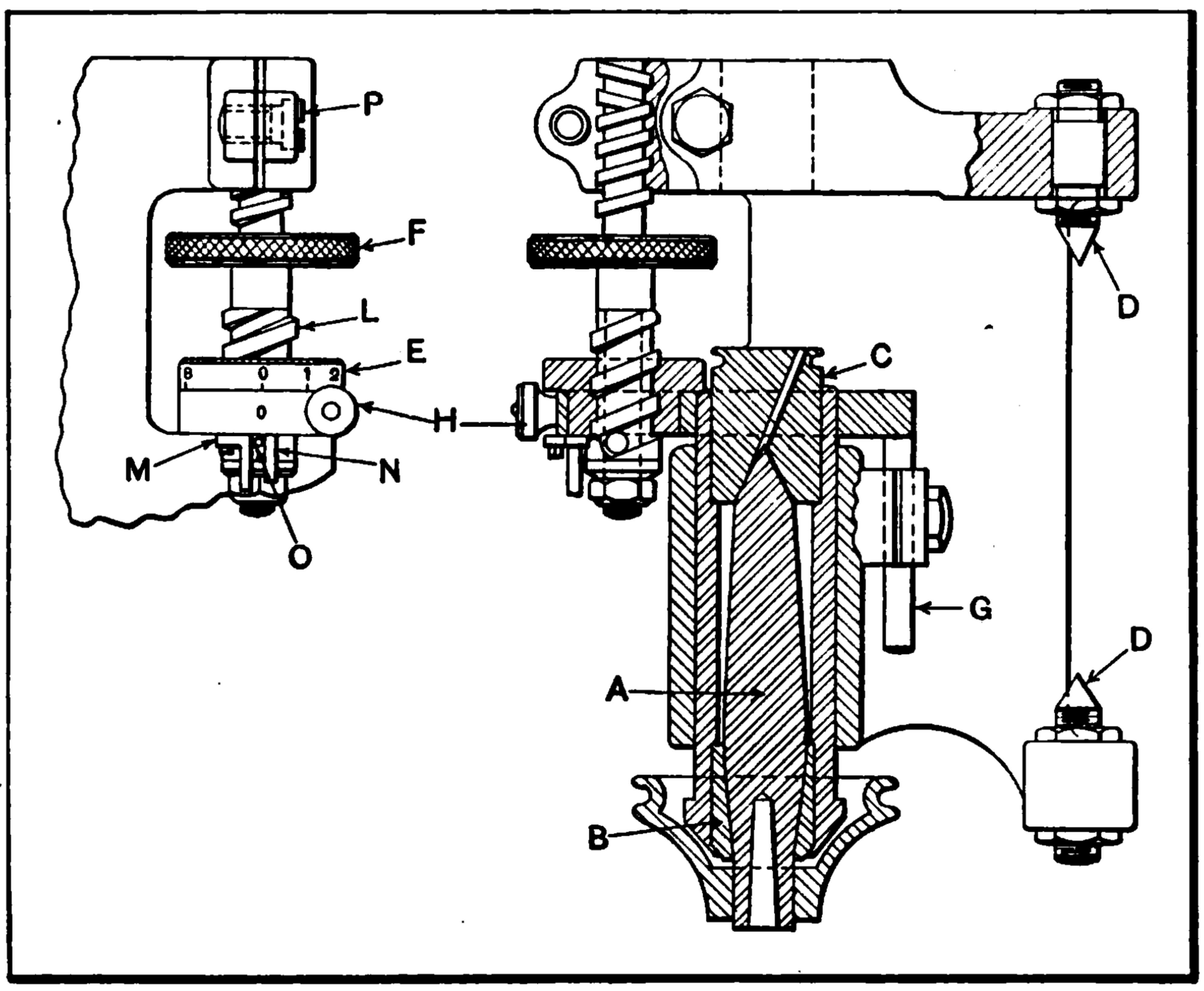


Fig. 4. Cutter-spindle Construction of Engraving Machine shown in Fig. 3

revolutions per minute. For soft steel, the speed is 4000 revolutions per minute and for tool steel, from 2500 to 3000 revolutions per minute. For engraving glass or on carbon brushes, a diamond tool is used. Black diamonds, like those used for truing grinding wheels, are employed for work of this kind. Cutters for ordinary work are usually made from Stubs drill rod, and after the cutters have been formed to the proper shape, they are hardened in water and drawn to a light straw color.

The construction of the spindle of the Gorton engraving machine is shown in Fig. 4. The cutter-spindle *A* is located inside a cylinder having a lower bearing *B* made of tool steel, hardened and ground. The upper end of the spindle is tapered to an angle of 60 degrees and runs in a hardened and ground conical bearing *C*, provided with an oil-hole for lubricating the spindle with fine sperm oil. The spindle carrier is held in position by conical screws *D*, which are so adjusted that the spindle frame is free to move, but without lost motion.

When the graduated collar *E* is set at zero, the cutter may be moved up or down by turning the screw *F*, and the stop-rod *G* may be set to control the depth at which the cutter operates. Instead of feeding the cutter down to a fixed stop, the graduated scale *E* may be used for feeding the cutter to any required depth, as measured from the surface of the work being engraved.

The divisions on the scale indicate hundredths of an inch. The thumb-screw *H* is released when collar *E* is to be adjusted. In order that the cutter may be raised and then lowered to the same point without difficulty, two stops *M* and *N* are provided between which the pin *O* operates. The screw *F* is turned until the cutter just touches the surface of the work, and it is then turned backward until pin *O* comes against stop *N*, which locates the cutter at the required depth.

The Pantograph Mechanism. The pantograph mechanism, a plan view of which is shown in Fig. 3, has one long and one short arm. The main pantograph arm carries the stylus or tracer point *K* which follows the copy or model that is clamped to table *H* at the rear of the machine. This arm is connected to the long arm *B* by means of a link *C*; the short arm *D* also forms a connecting link between arm *B* and the stylus bar *A*. The relation between the movement of the stylus point at *K* and the movement of the cutter is governed by the relative positions of the sliding blocks *E* and *F* on the long and short arms *B* and *D*. To set the pantograph for a given reduction, the bolts on slides *E* and *F* are loosened and these slides are then set at whatever distances from the datum lines are required to give the necessary ratio of reduction. As previously mentioned, the least reduction is one-third and, consequently, the graduations begin at 3. A table accompanying the machine shows the various positions for blocks *E* and *F* which are necessary to obtain any reduction from 3 to 1 to 30 to 1. The movable arms are provided with ball bearings to reduce friction to a minimum.

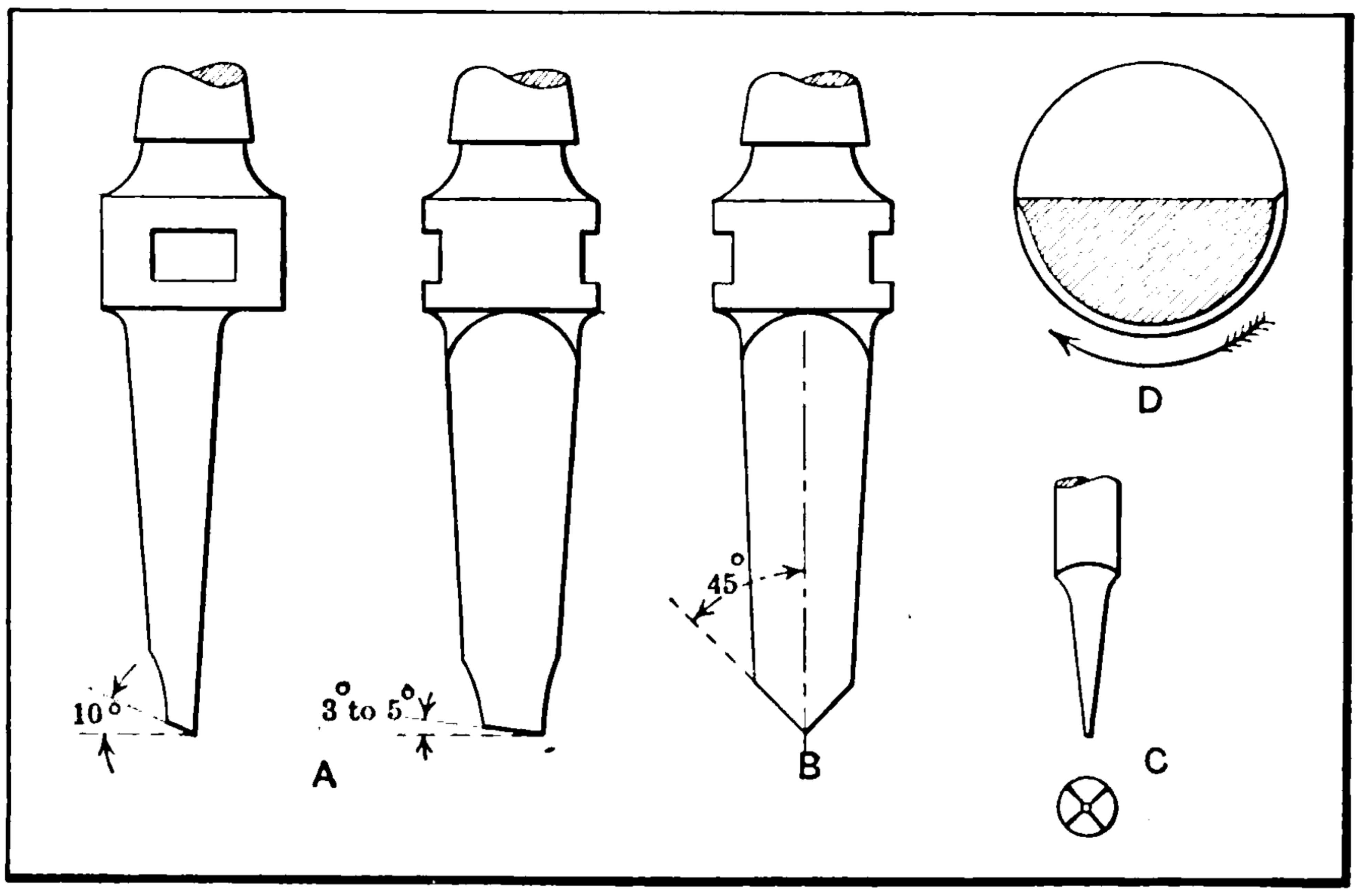


Fig. 5. Types of Cutters used for Engraving Operations

Cutters Used for Engraving. The three principal types of engraving cutters used in the machine shown by the plan view, Fig. 3, are illustrated in Fig. 5. The roughing type of cutter shown at *A* is flattened on one side and is sharpened on the point so as to penetrate the work like a drill when it is first fed down for starting a cut. It is ground with a slope of from 3 to 5 degrees, and is given a clearance of about 10 degrees. The cutter shown at *B* is used for finer work and is known as a conical pointed cutter. It is generally ground to an angle of 45 degrees and is made flat on one side, similar to the form shown at *A*. The cutter shown at *C* is used for very fine work. The cutting end is tapering and of square cross-section. This cutter is used only for operating against the side of an engraved surface and cannot be fed down into the work. cutters of this type are only about 0.100 inch in diameter, and are held in a chuck.

The cutters should revolve in a clockwise direction as viewed from above, and the cutting edge should be backed off as shown by the enlarged section *D*. The pointed cutter shown at *B* should be sharpened carefully, to insure that the point of the cutter will be absolutely true and that the entire cutting edge will have the proper amount of clearance. When grinding the small cutter shown at *C*, it is essential that the cutting end be true with the axis, and an indexing fixture is generally employed for grinding. The cutter is tested on the machine to see that the point runs true. The edges of this cutter should also be finished with an oilstone.

Making Patterns for an Engraving Machine. The "copy" or pattern used on an engraving machine as a guide for the tracer point is made of various materials, such as zinc, celluloid, hard rubber, and brass. In some cases, heavy paper or bristol board is used, especially when only a few parts are to be engraved and the expense of making a more substantial pattern is not warranted. Brass is often used when a large number of duplicate parts are to be engraved. These patterns are made in different ways, the method depending somewhat upon the accuracy required and the kind of pattern needed. If the pattern is for a new or original design, one method is first to lay out the design on heavy paper to an enlarged scale. This design is then used for engraving the pattern which is attached to the regular work-table of the machine. In order to provide a more positive guide for the tracer, several thicknesses of paper, cut to the required form, may be mountd on a sheet of metal with shellac. The shellac not only holds the paper in position, but hardens the edges which serve as a guide for the pantograph tracing point when engraving the pattern.

Another method of making the pattern is to engrave the required design directly upon the pattern by hand. The design is sometimes engraved by hand in a sheet of hard rubber which is either used as the regular pattern or is employed temporarily for engraving a duplicate in brass, especially when a very durable pattern is required. Still another method is to make an enlarged drawing of the design and transfer the outline to a sheet of transparent celluloid which is placed over the drawing. The celluloid is then cut out to conform to the design, thus obtaining a male and female model. This method is useful when making punches and dies of irregular shape.

Patterns for engraving letters are furnished in different styles and sizes by the manufacturers of engraving machines. These individual letters are arranged in a suitable holder in the desired position on the pattern or copy table, and are used as a pattern for engraving the work.

Reproducing Pattern from Sample. In many cases, manufacturers send an engraved sample which is to be duplicated. One method of making a pattern from a sample is as follows: The shape of the design is first transferred to tracing paper, either by a rubbing process or in any convenient way, and the design is then thrown upon a screen with a projecting lantern, to a scale which may be twenty times the size of the sample. The outline of the image is traced in pencil upon a sheet of manila paper, after which the tracing is tacked on a drawing board and any slight irregularities and distortions are corrected. The sketch is then cut out and mounted on a sheet of galvanized steel by using shellac, and by applying several thicknesses of paper an edge is formed which serves as a guide for the tracer point. This temporary pattern is used to generate a more substantial one either in brass or other material, as previously explained.

Making Masters for "Copy" on Gorton Machines. The George Gorton Machine Co. uses the following methods for making "copy" used on engraving and graduating machines of its manufacture. In making the copy for graduating scales and similar work, the lines are laid off by means of a dividing engine in cases where a high degree of accuracy is required; but for work that does not demand so high a degree of precision, the dividing head of the mill-

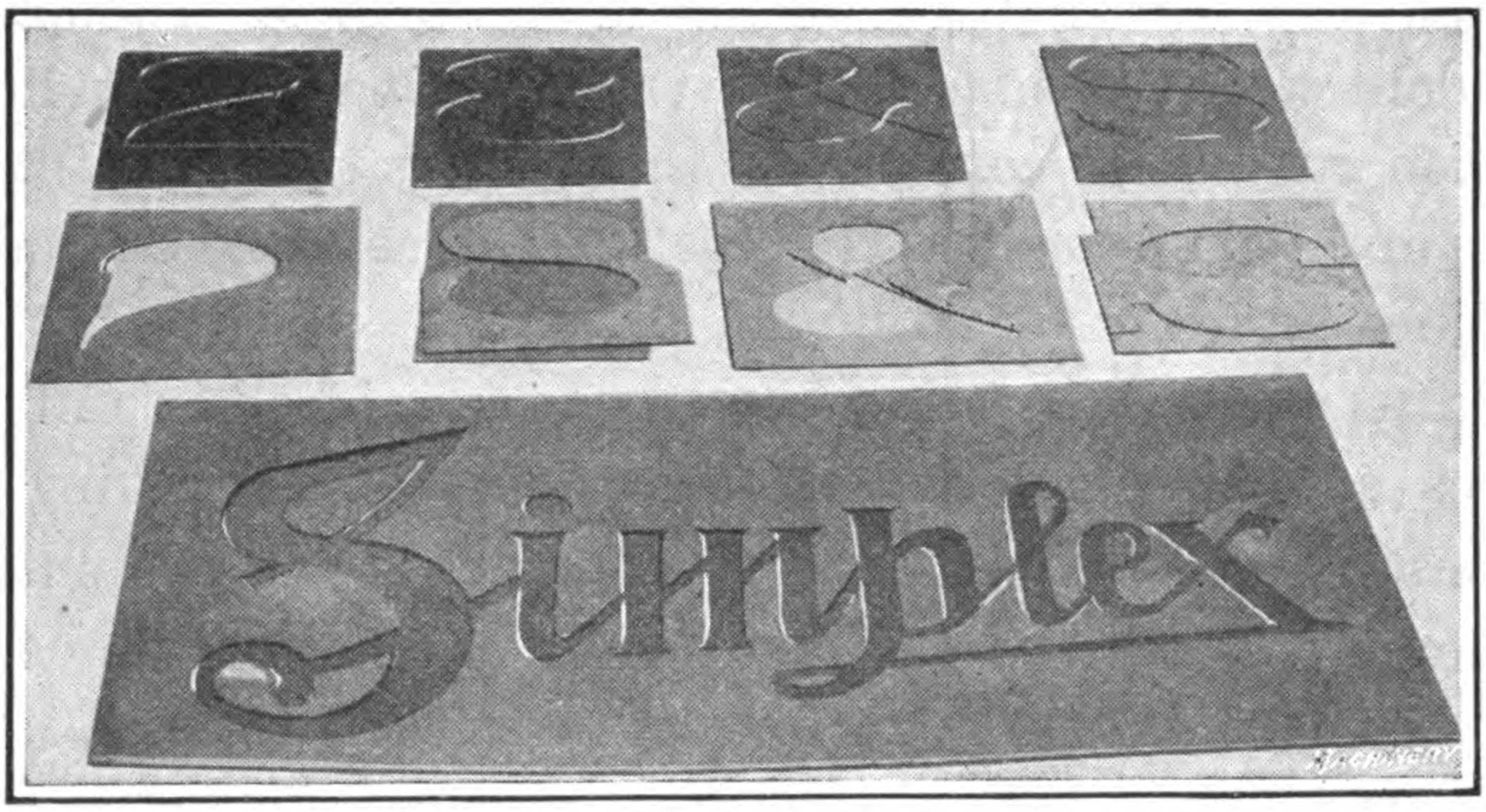


Fig. 6. Top Row, Master Copies for Permanent Use; Second Row, Sheet Metal Templets for making Master Copy; Bottom Row, Master Copy for Temporary Use, made of Cardboard and Varnished

ing machine or feed mechanism of the lathe may be relied upon to give sufficiently accurate results.

In cases where the Gorton machines are used for engraving, the "copy" for figures, letters or designs that are to be cut can be made by a variety of different methods, the most common of which is to cut out a templet from sheet metal or paper (if paper is used it must be varnished) and use the templet as copy for engraving a master from metal that will be used in cutting subsequent work produced on the machine. Fig. 6 shows in the top row a set of finished masters, and in the middle row, the sheet metal templets that were first cut out for use in making these masters.

It will be of interest to note that it is not always necessary to make a complete templet, because in any cases where the figure, letter, or design has straight lines of considerable length, it is often possible to use the slides on the ma-

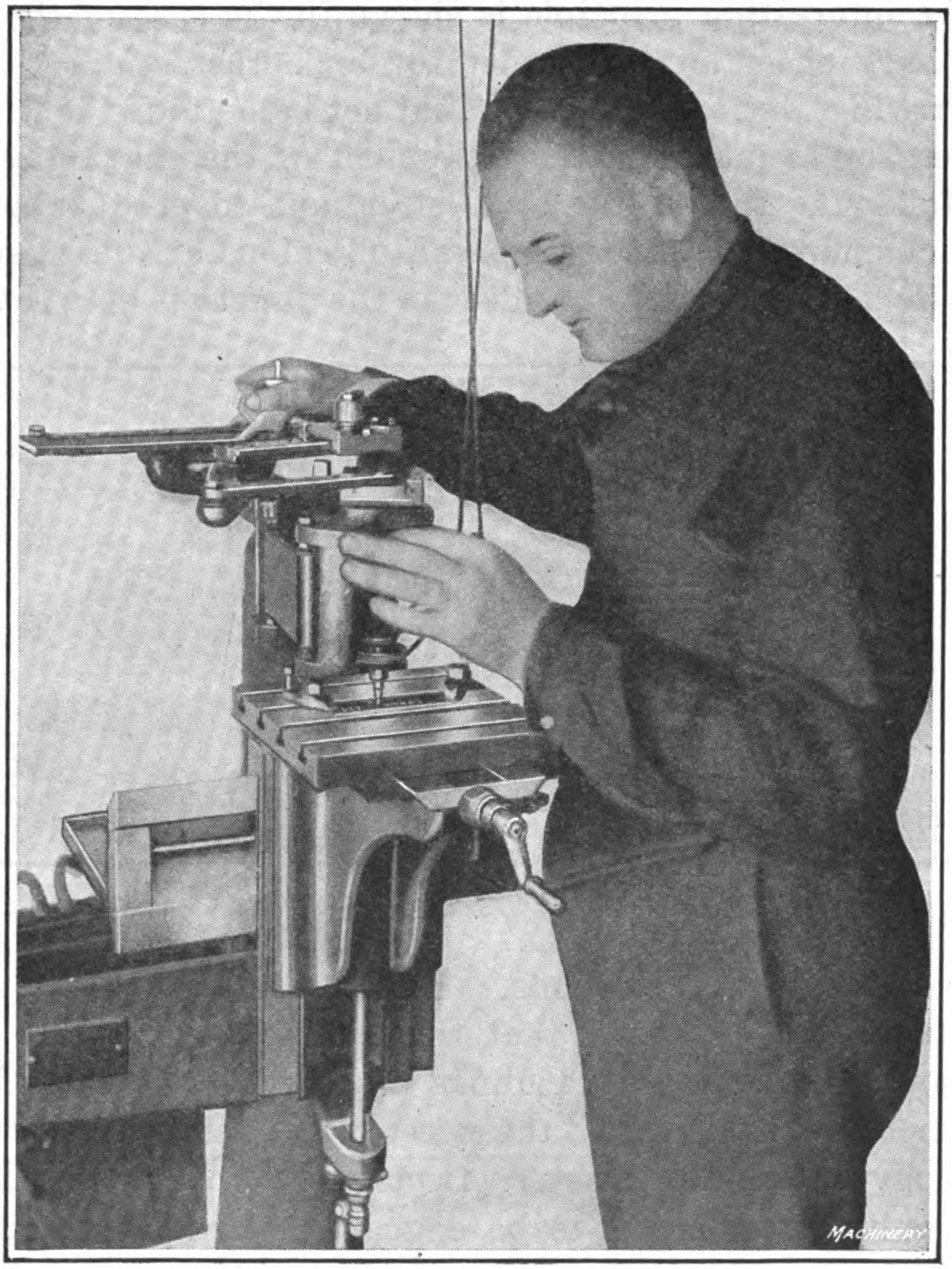


Fig. 7. Engraving Nameplate on Engraving Machine of Type shown in Fig. 3

chine for rapidly cutting such lines. For instance, in the case of the templet for cutting a 2, it will be seen that the curved stroke of the figure is the only part that is produced on the templet. After the templet has been followed to cut this curved stroke, the cross-slide on the machine is brought into action and the straight base of the figure is rapidly finished. Copy for letters and numbers is ordinarily made in $\frac{3}{4}$-, $1\frac{1}{2}$- and 3-inch sizes to fit the standard copy-holders provided on the machines.

An interesting principle is shown in the case of the preliminary sheet metal templet for an ampersand (&). In engraving, uniform results would not be obtained if it were necessary to interrupt the movement of the engraving tool in following the outline of a letter, and to produce a continuous movement of the tool, an ingenious arrangement of "switches" has been provided at the junction between the

Fig. 8. Examples of Flat Work done on Engraving Machine

upper and lower sections. It will be seen that these switches can be so set that the tool follows around continuously in cutting the upper and lower sections of the symbol. In most cases, the sheet metal templets are used as copy in making masters from metal, but where there are only a few pieces to be engraved, the sheet metal or paper templet is used as the copy from which engraving is done directly on the work. An example of this kind is shown in the case of the paper templet for engraving the word "simplex."

A Gorton engraving machine of the type shown in Fig. 3, is illustrated in Fig. 7 which indicates how the machine is used for engraving a nameplate. Quite a wide range of work can be handled on the Gorton machines, as will be seen from Figs. 8, 9 and 10, which illustrate typical examples of flat work on which the engraved design is in relief and intaglio, and of rolls on which the engraving and graduating operations have been performed

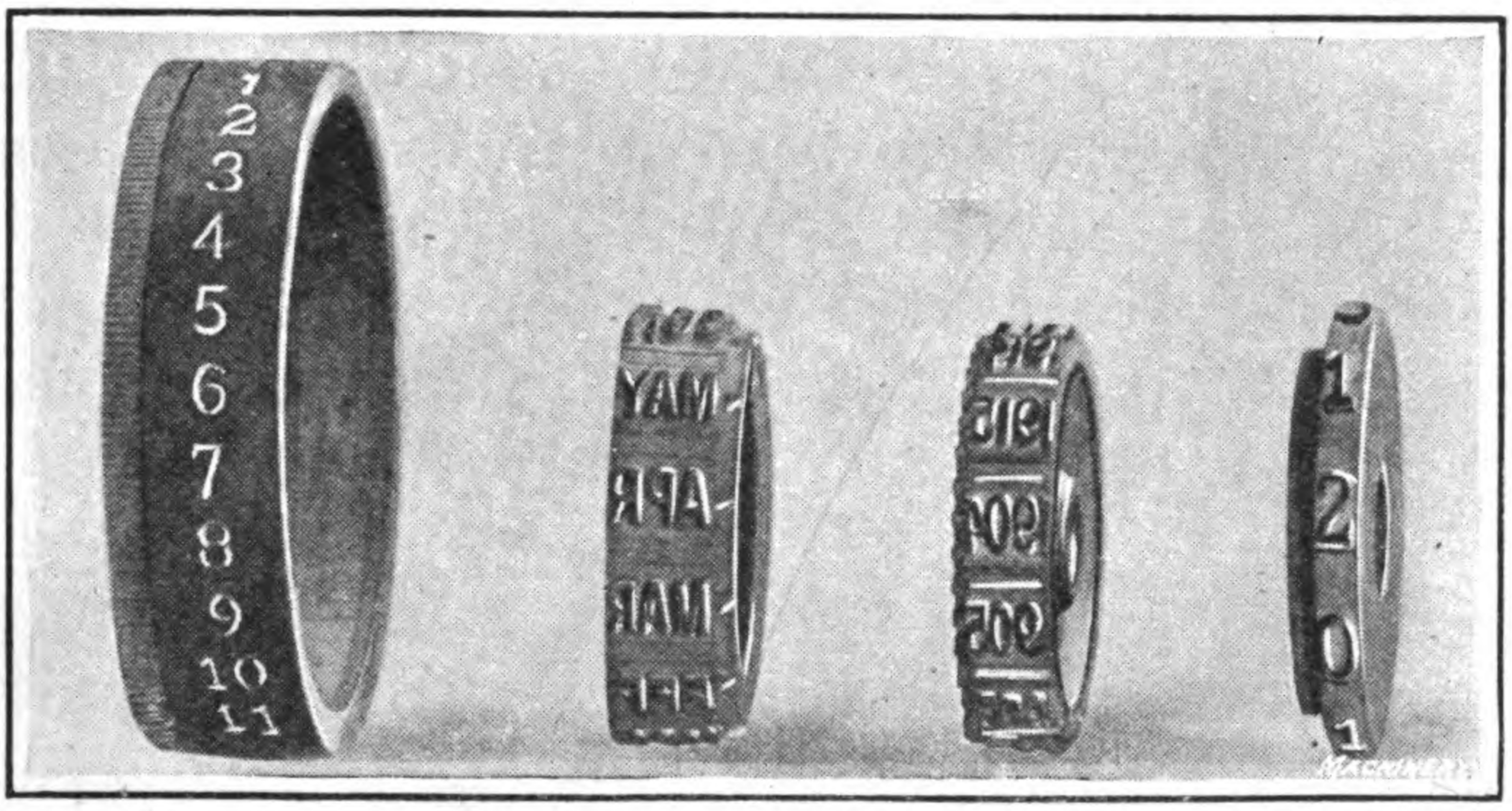


Fig. 9. Examples of Figures, Letters and Graduation Marks cut on Cylindrical Work

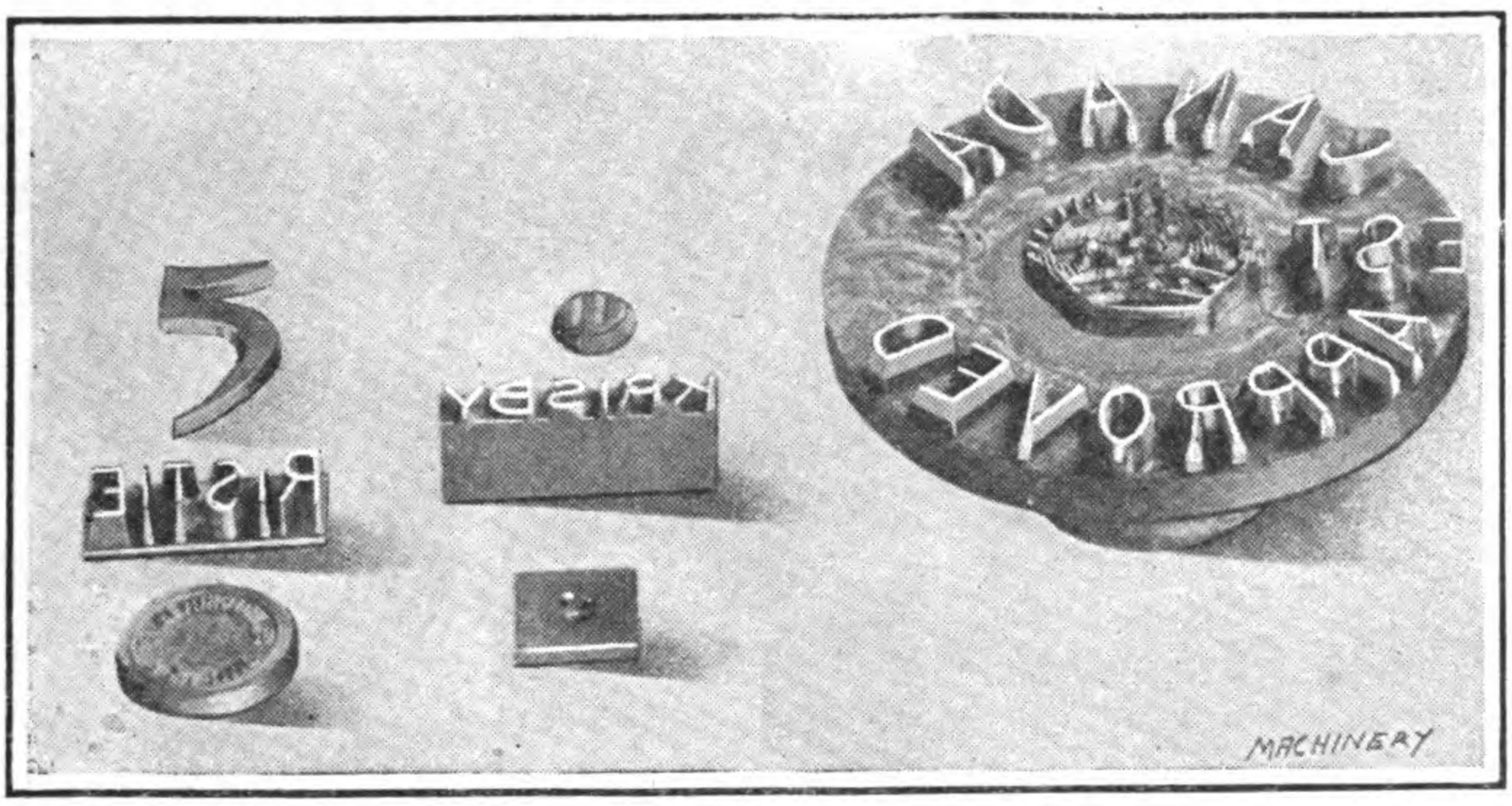


Fig. 10. Examples of Engraving where Design is in Intaglio and in Relief, illustrating Range of Work that can be handled on Engraving Machines

on a convex surface. Machines are shown in operation performing all these classes of work, and the description already given covers such operations, with the exception of engraving designs on rolls, for which a special fixture is used, (see Fig. 11). The work is held at the end of an arbor carried by the fixture; at the opposite end of the arbor is an index plate. In operating the machine, the master plate or copy is moved around so that the desired notation is brought under the stylus and the copy is then held in this position by means of a plunger that enters one of the index

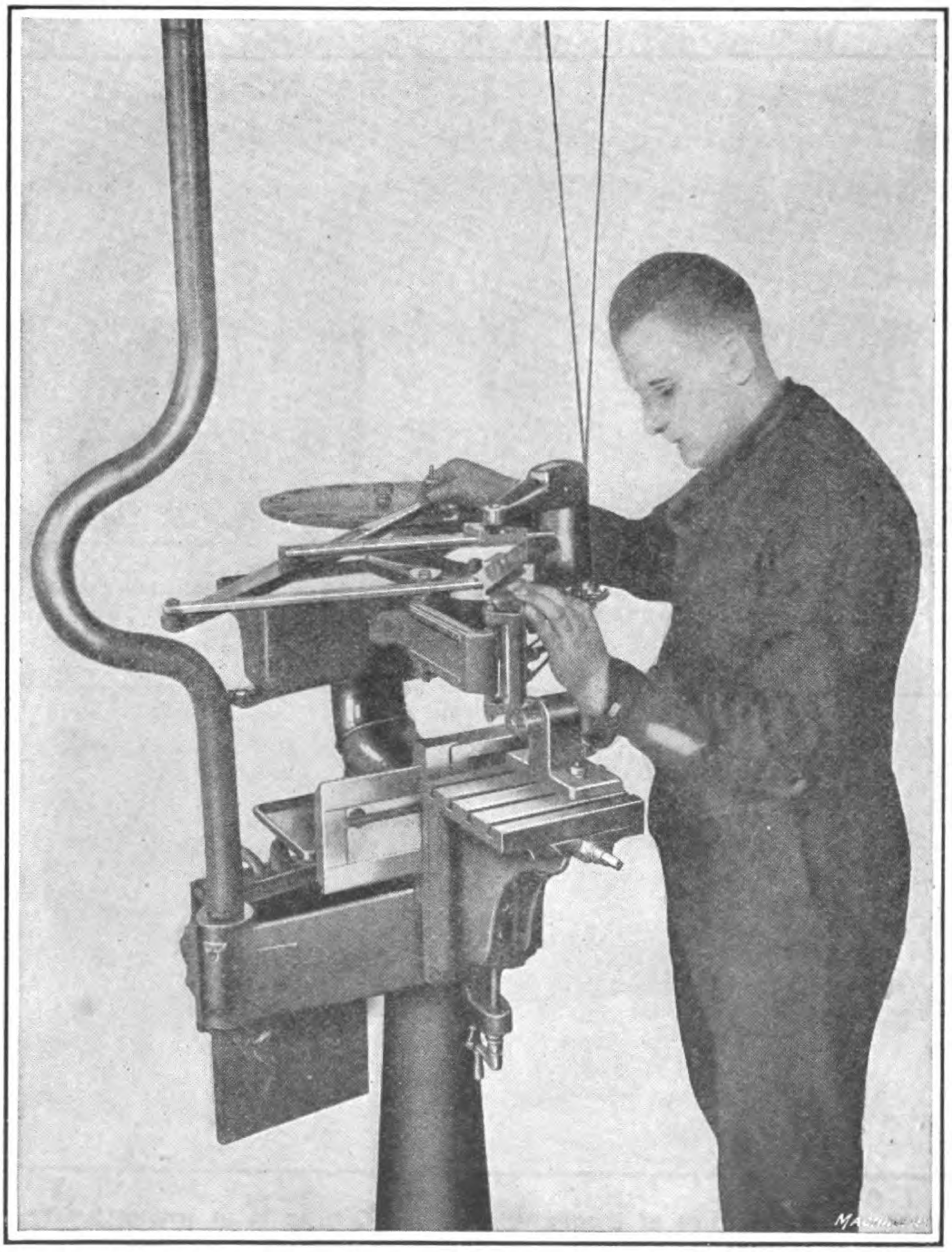


Fig. 11. Method of engraving Figures on Cylindrical Work —Illustration shows George Gorton Engraving Machine

notches in the periphery of the plate. The work is secured in the initial position by means of a plunger that enters one of the notches of an index plate at the rear end of the work-holding mandrel, after which the engraving operation is conducted in the usual way. To provide for engraving subsequent notations on the work, both the master and work are indexed, engraving and indexing operations being performed alternately until the job has been completed.

Engraving Surfaces of Varying Curvature. On at least one class of convex work, the curvature of each part to be engraved varies more or less, so that a single former for guiding the cutter vertically cannot be used. The mother-of-pearl handles used on revolvers and automatic pistols are an example of work of this kind. As each half of a pearl revolver handle is of different shape and thickness and no two are exactly alike, an individual former must be provided for every piece. A method of doing work

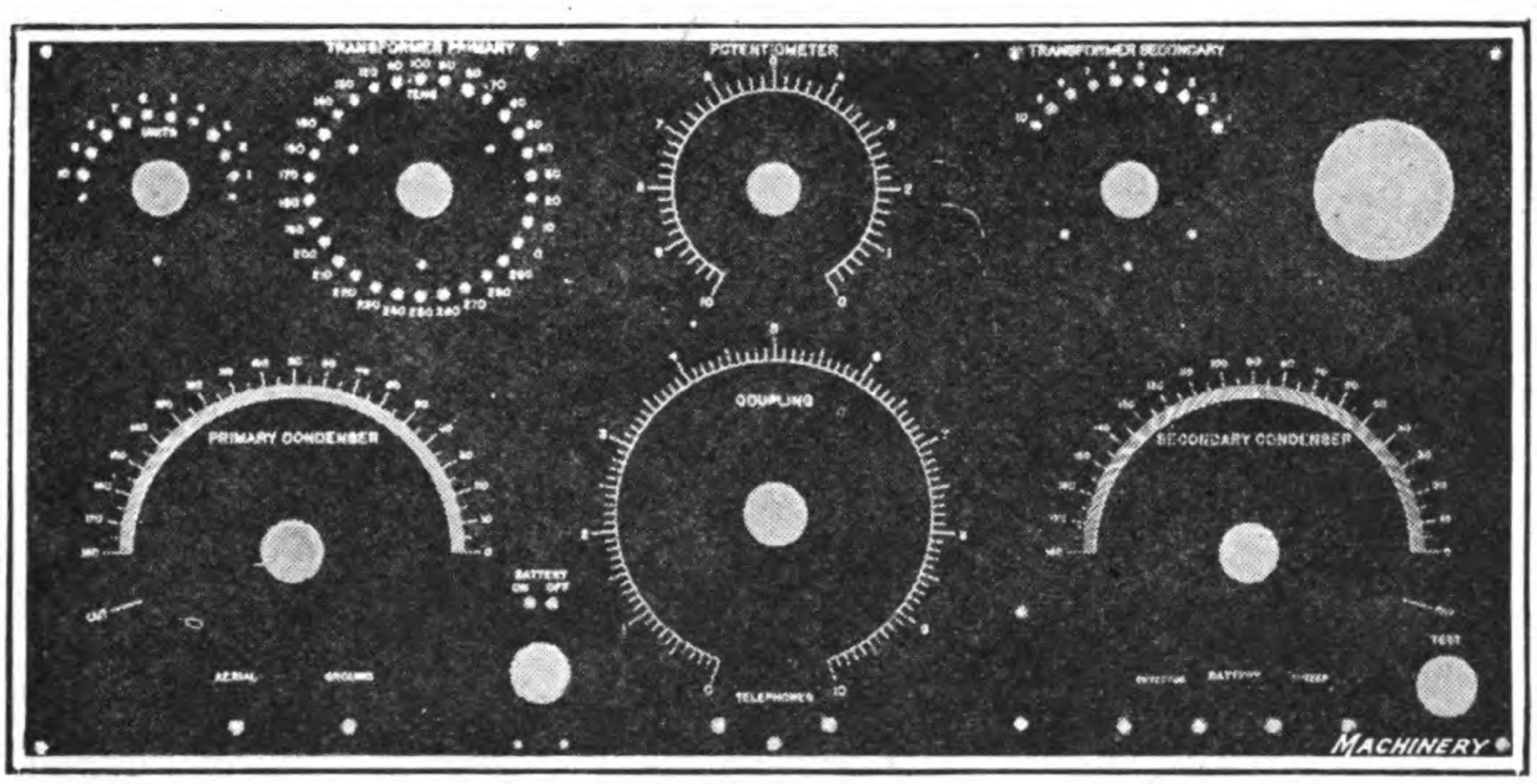


Fig. 12. Instrument Board for Marconi Wireless Telegraph Apparatus, on which all Graduating and Engraving Operations were performed on Gorton Machine

of this kind is as follows: Separate formers of sealing wax are made in a mold for each handle, and the pearl handle to be engraved and the wax former are sent to the engraving machine together. A special fixture is used for making these wax formers, so arranged that melted wax can be poured around the handle, which forms an impression in the wax. When the mold is being made, the handle is mounted on a plate which engages grooves in the bottom of the fixture. The jig for holding the handle on the engraving machine has corresponding grooves so that the handle is properly located with reference to the wax former. The latter is attached to the machine directly over the cutter-spindle where it is fixed in a dovetailed holder. A guide point on top of the cutter-spindle casing is held in contact with the former by a spiral spring.

Graduating Scales for Wireless Instruments. For engraving the various forms of scales used on the instruments of its manufacture, the Marconi Wireless Telegraph Co., employs machines operating on the pantograph principle in its plant at Aldene ,N. J. Most of these scales are graduated on plates or dials composed of "Bakelite" (a material resembling hard rubber), and in order to make the

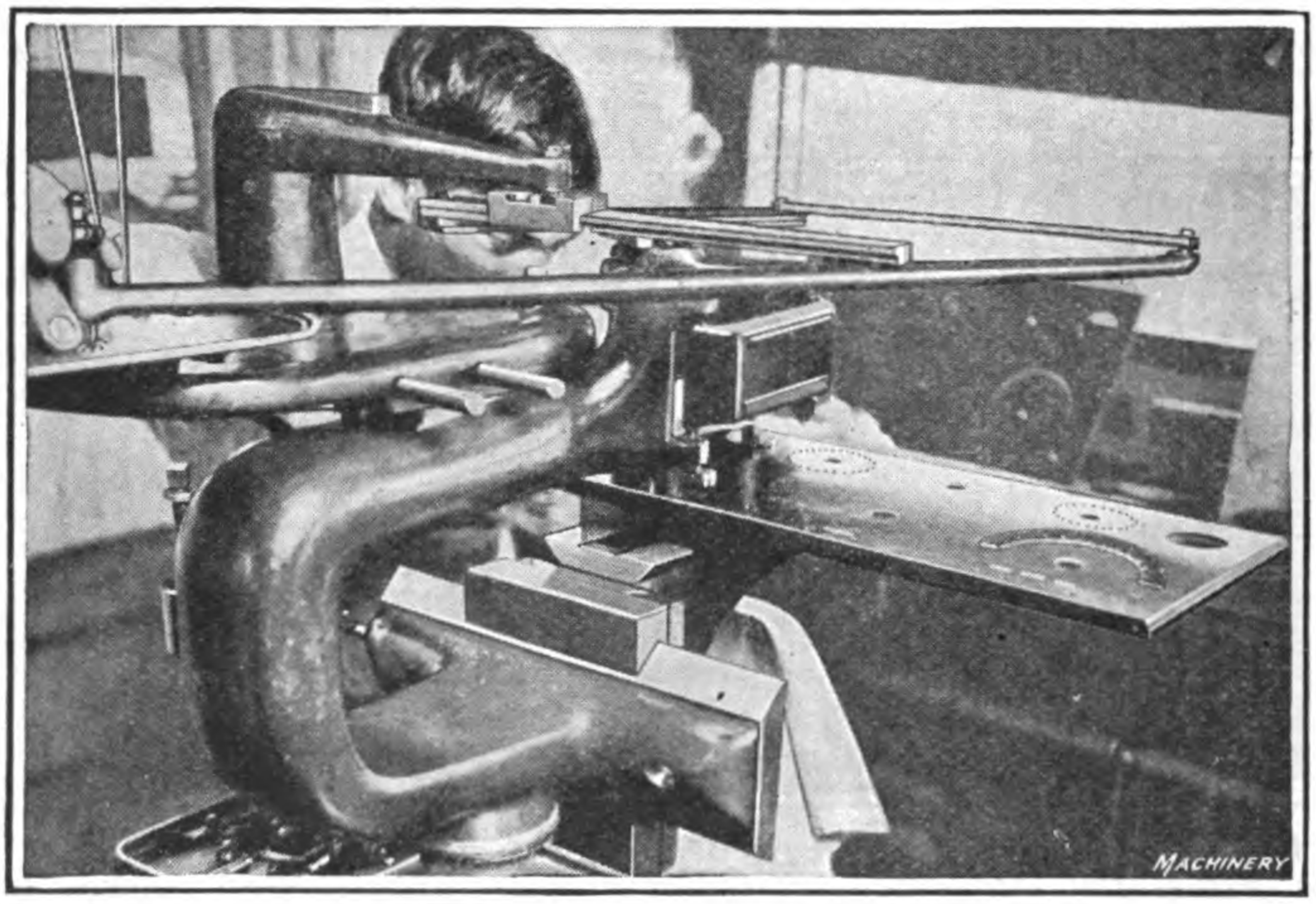


Fig. 13. Work of graduating Instrument Board of Type shown in Fig. 12

graduations easily read, zinc oxide mixed with paraffin is rubbed into the graduation marks after they are cut on the machines. This mixture hardens through exposure to the air, giving a high degree of durability, and as it affords a combination of white graduations on a black background, the scales are easily read. Fig. 12 shows an example of one of these graduated plates, and in Fig. 13 a graduating machine is shown producing work of this kind. A model is made in which graduations are cut to correspond with the required graduations on the work, and this model is set up in the copy-holder on the machine so that the tracer point can run over it. Various forms of engraving tools are used according to the nature of the work; where fine lines are to be cut the tool is generally in the form of a pointed "cannon drill," while for heavier classes of work end-mills of various forms are employed.

The size of model used also varies according to the character of the work. In cases where fine graduating is to be done on a relatively small area, it is desirable to make the model several times larger than the work, as it is more convenient to make it in that way, while in the case of

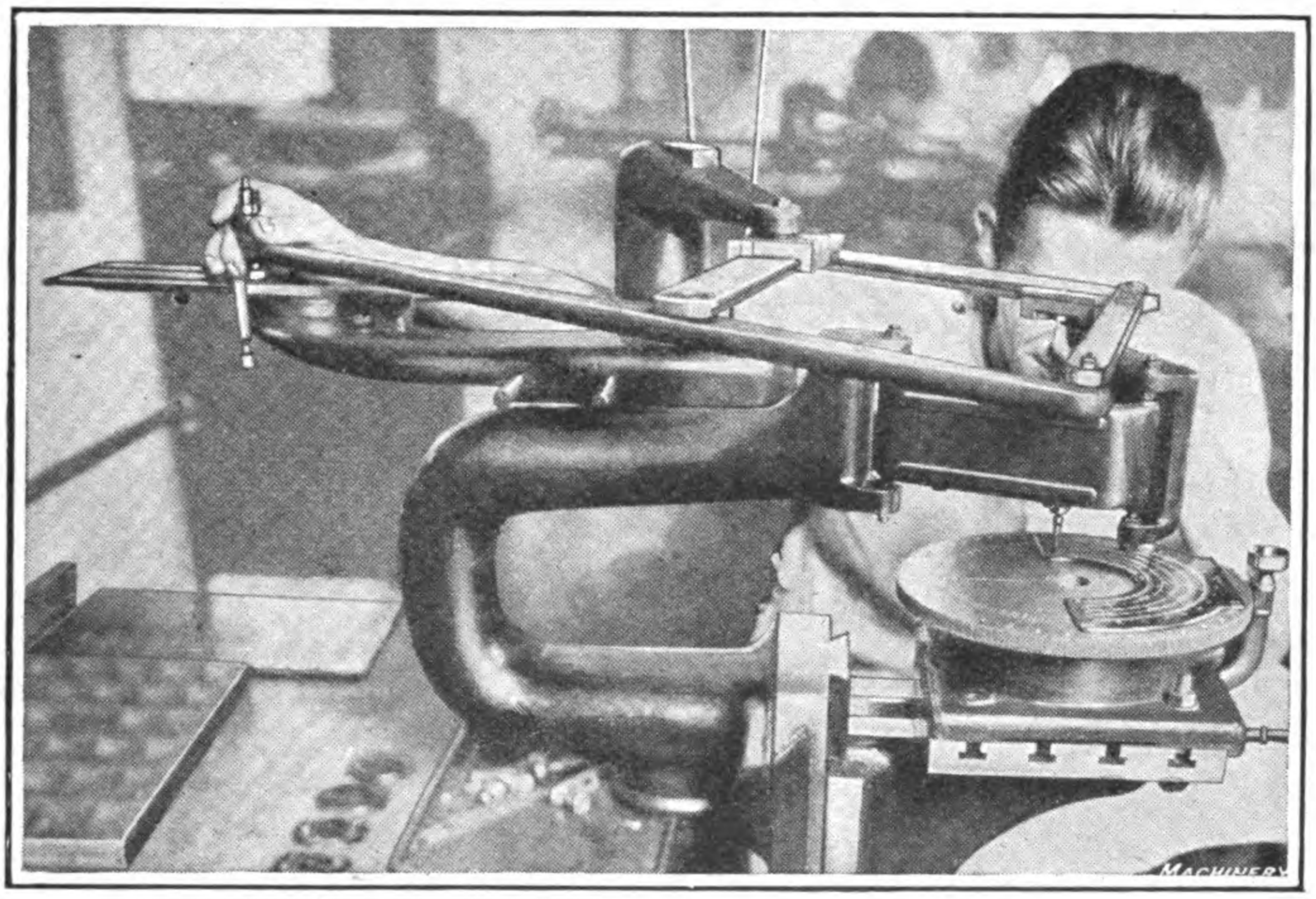


Fig. 14. Universal Indexing Fixture for graduating Standard Circular Scales

simple designs the model may be of the same size as the work or even smaller. Adjustment of the pantograph linkage is prvoided in order to obtain any required ratio between the size of the model and the work.

Fixture for Angular Graduations. In the manufacture of certain kinds of apparatus, there are many cases where circles have to be divided into degrees. In order to avoid having to make special models for this purpose, the expedient has been adopted of producing a universal fixture which is shown in operation in Fig. 14. This fixture is secured to the work-table and has a pivoted disk with 360 equally spaced teeth cut in its periphery. On the model table there is a simple plate with graduations cut in it of the required lengths for the scale to be produced on the work. The work is strapped to the top of the pivoted plate of the fixture and indexed space after space by means of teeth in the periphery of this plate. After each setting of the work has been made, the tracer point is drawn over the graduation mark on the model, which governs the length of graduations cut on the work. This fixture can be used for graduating any scales requiring circles or parts of circles to be divided into degrees. The illustration, Fig.

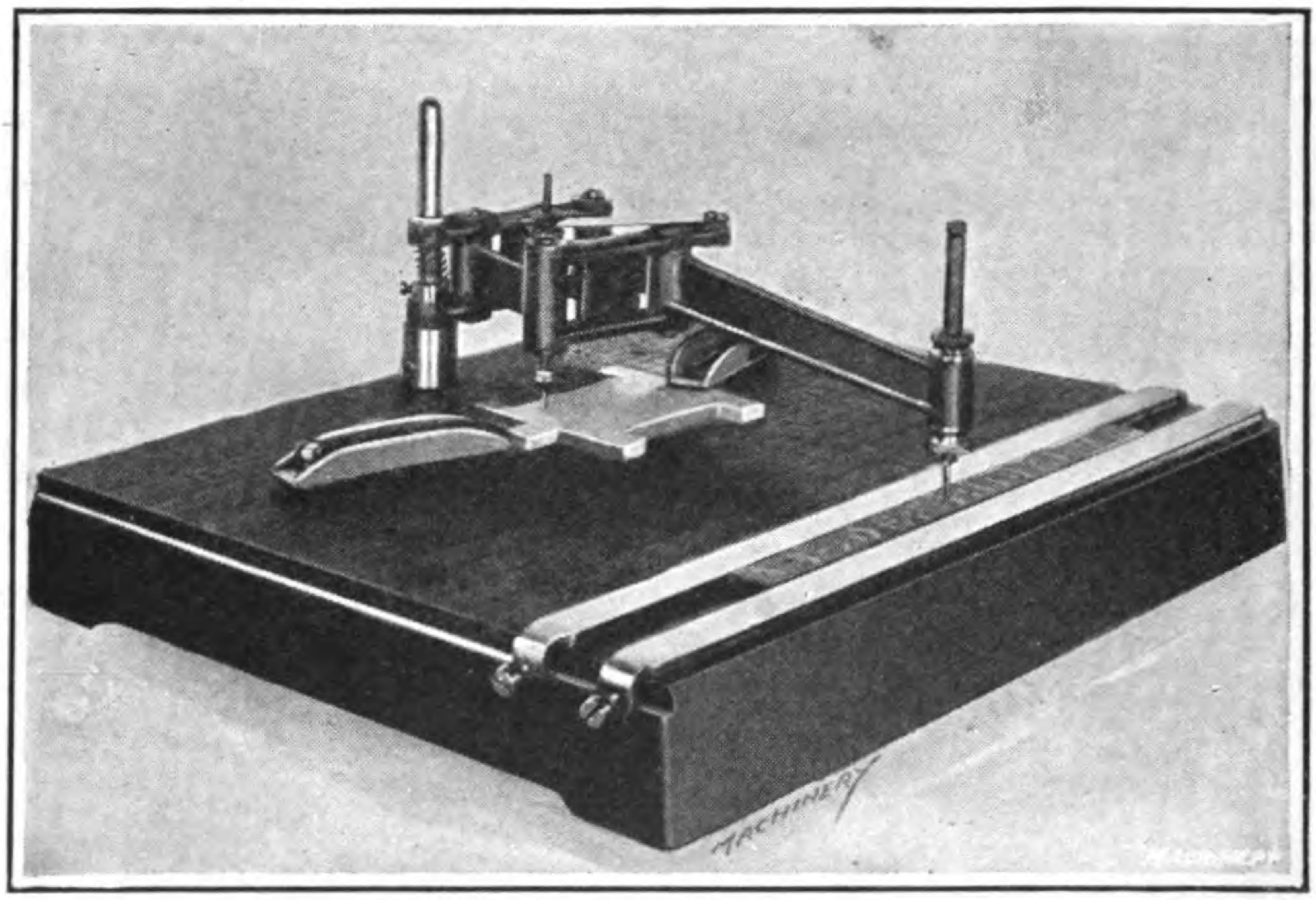


Fig. 15. Bench Type of Engraving Machine Suitable for handling General Classes of Work of Moderate Size

14, shows the machine being used for graduating circular scales for certain parts of wireless telegraph apparatus.

Small Engraving Machine for Use on Bench. The distortion resulting from the use of hardened steel stamps for marking gages and other forms of measuring tools or delicate instruments is generally recognized among machinists and toolmakers. The engraving machine illustrated in Fig. 15 was designed for marking all sorts of fine tools that might be injured by the use of stamps. A suitable resist is applied to the surface of the hardened tool and the machine is used for tracing the letters or designs required, which are afterward cut into the surface by applying an etching fluid. The machine operates on the pantograph principle. It is equipped with metal matrices or copy blocks which can be arranged like type in any desired combination of letters or figures.

In use, the stylus is guided by these matrices and the tracing point reproduces the lettering or figures on a smaller scale. The pantograph mechanism gives a reduction of 4 to 1 so that if 1/8-inch characters are required on the work, matrices with 1/2-inch face are necessary. The part to be etched is held in position on the table of the machine by the clamps shown, and the matrices are held in proper alignment by two parallel strips or bars, as the illustration shows. This machine is built by the Spicer Tabulating Machine Co., Washington, D. C.

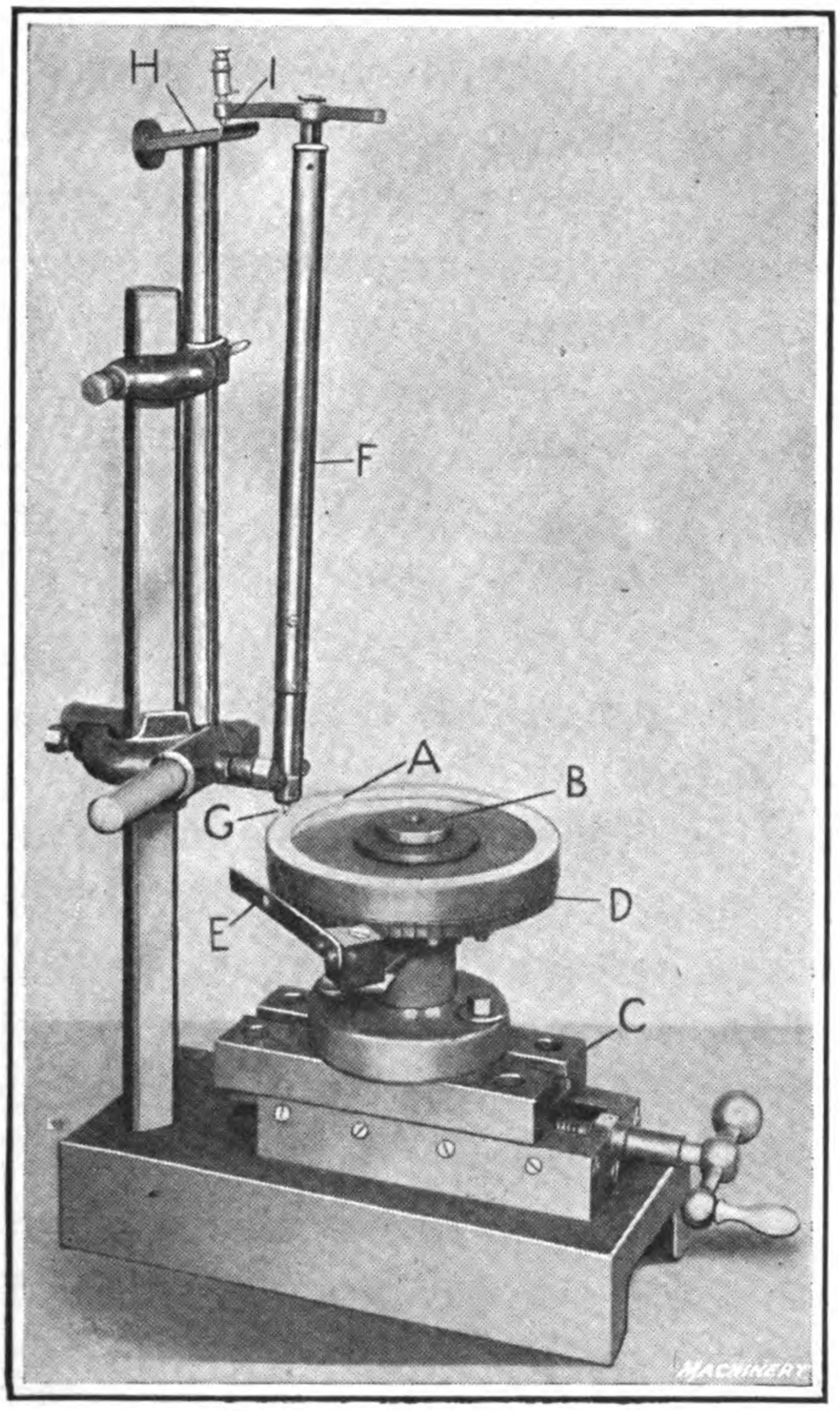


Fig. 16. Special Engraving Machine used for engraving Very Small Figures and Notations

Machine for Engraving Small Figures. In Fig. 16 is shown a machine built by William Gaertner & Co., and used in their instrument shop for cutting notations for different classes of work—especially for numbering graduated scales. The operation is similar to that of the machine shown by Fig. 7, Chapter I, except that in this case the work *A* is held on a vertical arbor *B* supported on a slide *C*, the position of which may be regulated for engraving work of various radii. Secured to mandrel

B is a notched index plate *D*, which is engaged by a plunger carried on spring *E*. It will be seen that the engraving tool is carried at the lower end of vertical arm *F*, which is pivoted at *G*, the ratio being such that the machine is adapted for cutting only exceedingly small letters. Master letters are secured to copy-holder *H*, and stylus *I* is run over these letters in the usual manner.

CHAPTER III

ETCHING AND ETCHING FLUIDS

ETCHING may be described simply as the removing of part of a substance so that a mark or design becomes visible by relief. It can be done mechanically, but the principal reason for not employing this means is that it is easier to do it chemically. A common method of etching names or simple designs upon steel is to apply a thin, even coating of beeswax, or some similar substance that will resist acid; then mark the required lines or letters in the wax with a sharp-pointed scriber, thus exposing the steel (where the wax has been removed by the scriber point) to the action of an acid, which is finally applied.

Coating Surface to be Etched. One of the most important things, and one which is most frequently overlooked when etching, is the proper application of the ground which is used to protect the parts from the action of the acid. Some form of wax on which etching fluid has no action is generally used for this purpose. If the wax is too soft, the point of the engraving instrument will cut through, leaving only a very fine line so that the fluid has little opportunity of reaching the metal, as a layer of air will prevent actual contact. On the other hand, if the wax is too hard or brittle it will be broken and split along the edges of the engraved line in the same manner that glass will break when struck, and while these minute fractures cannot be seen, the result will be a blurred design.

The nearest approach to a perfect ground for general purposes is beeswax of the proper consistency, which can be easily applied in any desired thickness. Before applying the wax, it is important that the surface be thoroughly clean and absolutely dry, and the difference in temperature between the wax and the article to be etched should be slight. The surface to be coated can be dipped in the melted wax, or if desired, the entire piece can be immersed. In this way, a uniform coating of wax can be given to the work, and the danger of acid stains will be eliminated. If it is necessary to dip the piece into melted wax, the article should be kept immersed for a few moments until it acquires the same temperature as the molten wax. The necessity of having the surface perfectly clean and dry is easily explained, for if there is a film of oil on the surface, the wax will cover but not adhere, and in consequence the etching fluid will run under the wax and produce a smear or blur. The same effect is produced by moisture, except that in this case the blur is likely to be worse, as there is an affinity between water and etching fluid causing spreading. To apply a very thin coating of beeswax, place the latter in a silk cloth, warm the piece to be etched, and rub the pad over it. Regular coach varnish is also used instead of wax, as a "resist."

Etching Fluids for Steel. An etching fluid ordinarily used for carbon steel consists of nitric acid, 1 part; water, 4 parts. It may be necessary to vary the amount of water, as the exact proportion depends upon the carbon in the steel and whether it is hard or soft. The acid oxidizes the metal along the lines that have been exposed by the marking points of the graduating machine, and leaves these lines darker than the surrounding metal so that they may readily be seen. For hard steel, use nitric acid, 2 parts; acetic acid, 1 part. For high-speed steel, nickel, or brass, use nitro-hydrochloric acid (nitric, 1 part; hydrochloric, 4 parts). For high-speed steel it is sometimes better to add a little more nitric acid. For etching bronze, use nitric acid, 100 parts; hydrochloric acid, 5 parts. For brass, nitric acid, 16 parts; water, 160 parts; dissolve 6 parts of potassium chlorate in 100 parts of water; then mix the two solutions and apply.

A fluid that may be used either for producing a frosted effect or for deep etching (depending upon the time it is allowed to act) is composed of 1 ounce of sulphate of copper (blue vitriol); 1/4 ounce of alum; 1/2 teaspoonful of salt; 1 gill of vinegar, and 20 drops of nitric acid. For aluminum, use a solution composed of alcohol, 4 ounces; acetic acid, 6 ounces; antimony chloride, 4 ounces; water, 40 ounces.

Etching Names on Tools. The National Twist Drill Co. employs the following method for etching on cutters and other tools: The steel is brushed with asphaltum varnish, which is allowed to stand until it thickens and hardens to the right degree; then the desired inscription is pressed through the asphaltum with a rubber stamp and the etching fluid (nitro-hydrochloric acid or *aqua regia*) is applied with a medicine dropper. Practice and experience are required to judge just when the varnish has dried to the right consistency.

A similar method, which has been successfully used for etching names on cutlery, is to coat the surface with gum guaiacum varnish. A rubber stamp having the name or design is then moistened with a thin layer of potash solution. When this stamp is applied to the work, the varnish is "cut" by the potash wherever the coated stamp comes into contact with it; the surface is then brushed lightly with water in order to remove the loosened varnish and expose the lettering or design, which is then etched by applying dilute nitric acid. The rubber-stamp method is a very cheap and rapid process. One method of applying the potash is to press the stamp against a pad soaked with the solution.

The action of etching fluids on steels varies somewhat according to the composition, high-carbon and alloy steels being acted upon more slowly than low-carbon steel or wrought iron. Etching fluids that work successfully on low-carbon steel may not work well on high-carbon steel or cast iron. The usual difficulty is that the carbon liberated by the etching fluid settles to the bottom and prevents further action. This can be overcome by frequently renewing the acid and cleaning out the carbon deposit so that the fresh acid comes into direct contact with the metal.

Etching Brass. The first step in etching is to see that the parts that are to be etched are carefully ground and polished. The only cleaning that will be found necessary can be satisfactorily done by wiping the work with a dry rag. One method of etching brass is as follows: First, heat the work and then dip it into molten paraffin, after which it should be removed and allowed to stand until cool. The pattern that is to be etched is marked in the paraffin in order to expose the metal. The etching is done with undiluted nitric acid. If the etched lines are to be very deep, the work should be immersed in lukewarm water occasionally to remove the copper nitrate which forms in the etched lines. This will prevent the lines from spreading. It is only necessary to leave the work under water for a few seconds in order to remove the copper nitrate.

The preceding instructions also apply to etching steel with the important exception that the etching solution is composed of 1 part of nitric acid and 1 part of hydrochloric acid. The paraffin may be removed from the work by first dipping it in boiling water and then in cold water; this treatment causes the paraffin to contract and peel off.

For etching brass, a satisfactory ground can be made from equal parts of beeswax, Burgundy pitch, and asphaltum. These constituents are melted together and thoroughly stirred in order to secure a uniform mixture. This ground is warmed before using and spread evenly over the surface that is to be etched. After the ground has had time to cool, it is removed from those sections of the metal that are to be etched, after which the etching fluid is applied. A satisfactory etching fluid consists of 1 part of nitric acid to 4 parts of water. After the etching has been completed, which takes only a few minutes, the work is dipped in hot water to wash off the acid. The surface of the work can then be cleaned by wiping it with a cloth dipped in benzine or gasoline.

For use on brass castings, the following method is recommended: After cleaning the work with gasoline, place it in clean boiling water. A pot of beeswax is melted and kept at a temperature of from 200 to 250 degrees F., by standing it on a gas plate or some other heater that will retain the desired temperature. After the work has been washed, the surface to be etched is painted with wax and the work is then hung up to cool. The surplus wax will drain off and some sort of pan should be provided to catch the drippings. This process leaves a very thin coat of ground which adheres firmly to the metal. The preheating tends to bind the ground securely.

The following is a satisfactory formula for an etching solution: Nitric acid, 16 parts; hydrochloric acid, 4 parts; water, 100 parts. Dissolve 6 parts of potassium chlorate in 80 parts of water. The two solutions produced in this way are then thoroughly mixed and allowed to stand for a few minutes until the gases have escaped. The solution is then stirred, after which it is ready for use.

Etching Glass. A simple method of etching glass is to coat it with melted paraffin, and draw the pattern to be etched in the wax with a sharp needle point. Then expose the glass to the action of vapor of hydrofluoric acid, produced by the action of warm hydrochloric acid on fluorspar. The gas must be generated in a lead vessel, as it attacks most substances. It is very poisonous, and therefore care must be taken not to inhale it. A little pigment is sometimes rubbed into the graduations to make them show more plainly.

Dry Etching on Glass. For dry etching on glass, as required for graduating volumetric glassware used in scientific laboratories, etc., etching and printing materials were obtained, before the war, from a company in Germany. These include one bottle of salt and one bottle of printing ink (one kilogram etching salt under label Berliner Kalt-Aetzsals fur E. Nienstadt's Trocken-Aetzverfahren U.S.W.) and ¼ kilogram printing material (Druckmasse) for a dry etching process. One kilogram of the salt, at that time, cost about 15 marks ($3.57); ¼ kilogram printing ink, 5 marks ($1.19); postage, etc., about 5.20 marks ($1.24), which did not include duty.

In using this method of etching, it is necessary to use gelatine pads, which could probably be purchased from some of the companies making duplicating materials. However, these pads can be made by heating together over boiling water 100 grams of photographic gelatine, 160 cubic centimeters of glycerine, and 100 cubic centimeters of water. This will make six pads 0.5 by 5 by 20 centimeters in size. When thoroughly mixed, pour the liquid into molds which may be most conveniently made of five separate pieces. The bottom and three of the sides are made of pieces of brass held together by screws, while the fourth side is made of a plate of glass with the inside surface ground. This plate of glass is held in place by two clamps. Before filling the mold, a thin coating of grease or graphite is applied to the inside surface of the metal parts so that they may be easily removed from the gelatine pad after it has cooled. For stamping, the side of the gelatine pad is used that was next to the ground glass at the time the pad was molded.

A gelatine roller is made of the same mixture as the pads, and this roller is cast on a core of metal tubing which is left permanently in the roller. A convenient mold may be made of thin glass tubing, 2 centimeters in diameter and 7 centimeters long, into one end of which is fitted a stopper with a hole in the center. The core of 6-millimeter brass tubing is held in place by fitting one end into this stopper and the gelatine mixture is poured into the mold. After the gelatine has cooled sufficiently the glass tubing is broken away from it and the handle attached to the roller.

Next it is necessary to make a stamp corresponding in design to that of the marking it is desired to put on the glass. With the gelatine roller, spread a thin layer of printing ink on a smooth glass plate, and from this use the roller to apply a uniform layer of ink on the gelatine pad, by first running the roller over the ink on the glass plate and then over the pad until the proper thickness has been obtained. From the inked gelatine pad, the metal stamp is used to transfer an inked impression to a clean gelatine pad, care being taken not to press too hard with the metal stamp and also to re-ink the stamp before making each new impression.

These inked impressions on the gelatine pads are transferred to the glass, which is then sprinkled with the etching salt, using a camel's hair brush to remove excess salt from the glass where it does not adhere to the ink. The salt is then exposed to the action of hot steam until a clear narrow border appears along its edges with a slight cloudiness outside. After steaming, it may be found necessary to let the work stand for a few minutes, but as soon as the stamp appears to be finished it should immediately be wiped off. A good stamp should be white and clean cut.

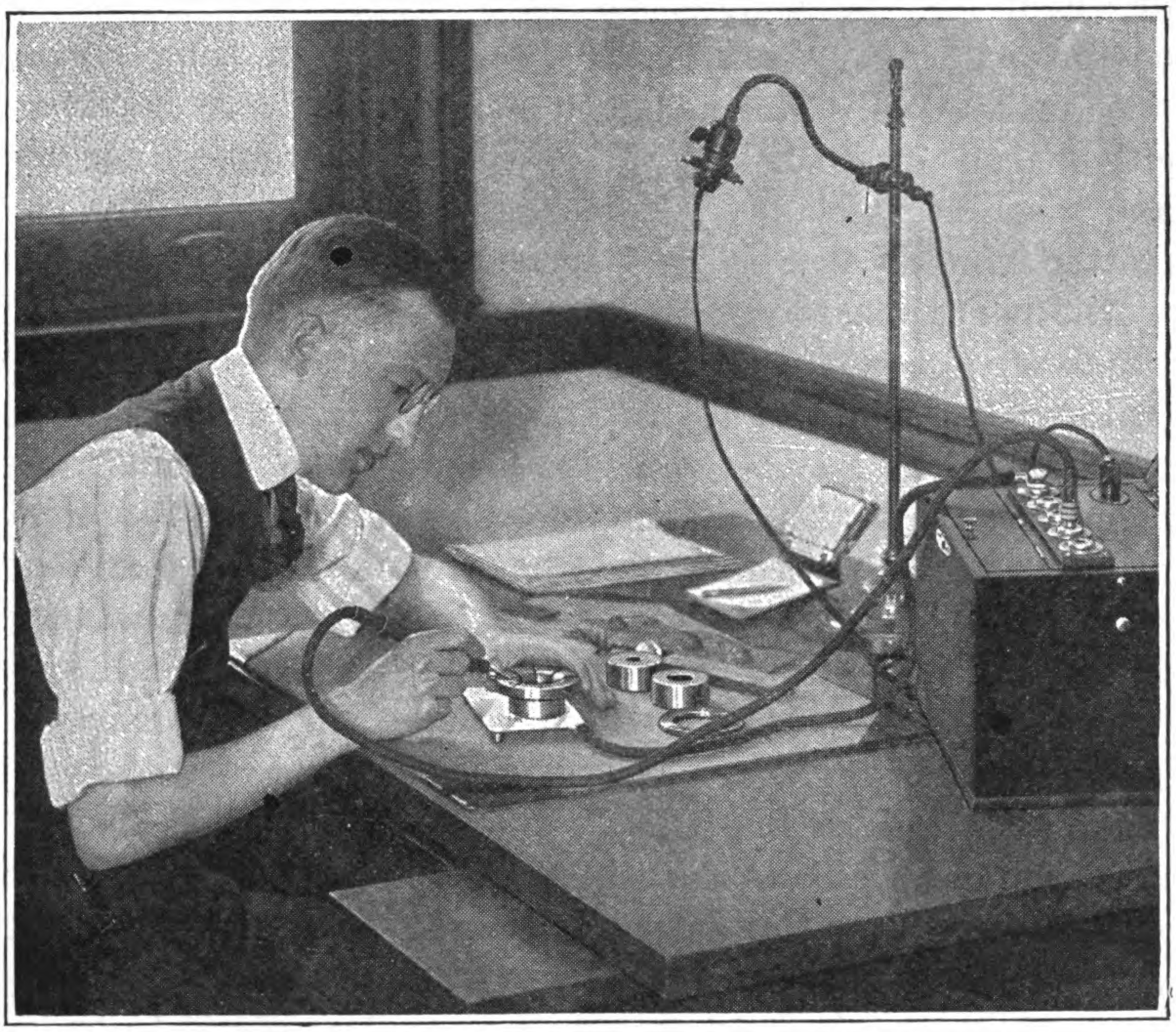
Attention is called to the fact that the amount of time a salted impression is allowed to steam will vary considerably with atmospheric conditions, so that in order to obtain good results at any time, past experience in the use of the method will prove of value. Good results may be obtained by heating the salted impression over a gas flame until it turns to brown and then to white; but apparatus which has been graduated must not be heated to a temperature where deformation of the glass will cause a change in the volmetric capacity. The gelatine pads are cleaned by wiping them off with strong alcohol; water cannot be used, as it will dissolve the gelatine.

In order to obtain the best possible results, the etching salt should be perfectly dry and ground rather fine. If too coarse, it produces a ragged stamp, but if too fine a sufficient quantity will not adhere to the inked impression. The salt is dried by placing it in a metal can with a tight fitting cover, in which there is a small hole to allow water vapor to escape. This can and its contents are heated to about 50 degrees C., which may be done by setting the can in a water-jacketed vessel and running a stream of hot water through the vessel. After drying, the salt is powdered, and when not in use it is kept in a tightly coverd vessel.

"Resists" Used for Graduating. Various acid-resisting materials are used for covering the surfaces of steel rules. etc., prior to marking off the lines on a graduating machine. When the graduation lines are fine and very closely spaced, as on machinists' scales which are divided into hundredths or sixty-fourths, it is important to use a thin resist that will cling to the metal and prevent any undercutting of the acid; the resist should also enable fine lines to be drawn without tearing or crumbling as the tool passes through it. One resist that has been extensively used is composed of about 50 per cent asphaltum, 25 per cent beeswax, and, in addition, a small percentage of Burgundy pitch, black pitch, and turpentine. A thin covering of this resisting material is applied to the clean polished surface to be graduated, and after it is dry the work is ready for the graduating machine. For some classes of work, paraffin is used for protecting the surface surrounding the graduation lines to be etched. The method of application consists in melting the paraffin and raising its temperature high enough so that it will flow freely; then the work on which the graduating is to be done is held at a slight angle and the paraffin is poured on its upper edge. As the melted paraffin flows across the surface of the work, the latter will be covered with a thin protective coating.

Electrical Etching Apparatus. In all shops where small tools, milling cutters, saws, etc., are used, the occasion frequently arises for applying various marks. This may be for the purpose of branding the tools with the name of the shop in order to avoid theft; it may be found necessary to designate the size of a tool or the operation for which it is employed, and numerous other occasions may arise which make it necessary for a tool to be marked. To meet the requirements of this work an electric marking apparatus known as the "etchograph" was developed. It consists of a transformer for connection with an ordinary electric lighting circuit to provide for obtaining the required current and voltage for operating the etchograph. Two leads are taken off from the secondary of the transformer, one of which runs to a steel plate of considerable size upon which the work to be marked is placed.

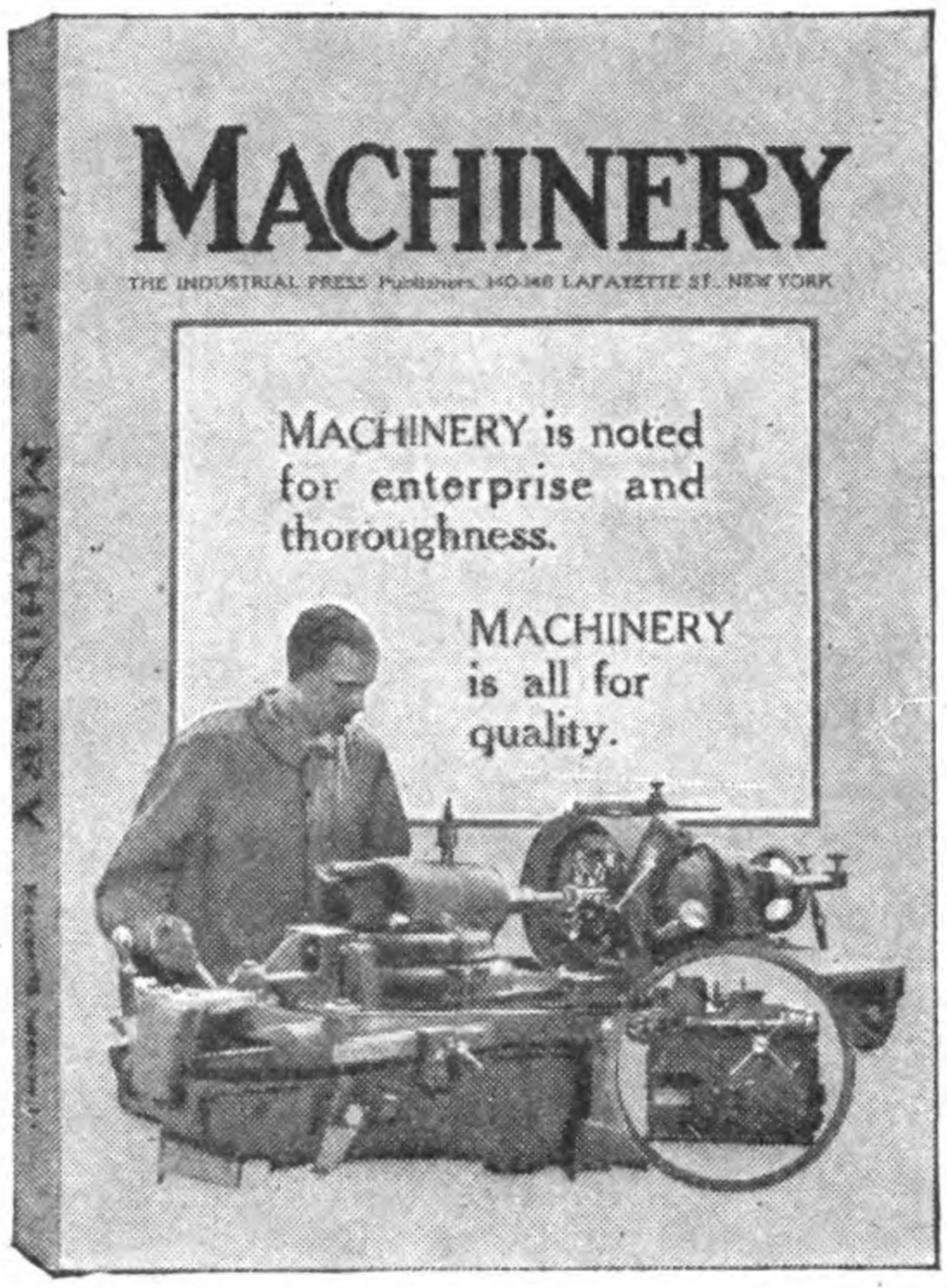
The other lead runs to what is known as the "pencil" of the etchograph. This pencil has a hardened rubber handle and a clamp at the end to which is secured the lead from the transformer. This clamp also carries a small copper point, made from an ordinary piece of wire, with which



Electrical Etching Apparatus for Use in marking Tools, Gages, Dies, etc.

the marking is performed. As this point is drawn over the surface of the work, the higher electrical resistance of the iron or steel to be marked results in producing a burn on the surface of the work, leaving a dark oxide mark on the metal. This apparatus is adapted for use in connection with standard alternating current of 110 volts, 60 cycles, and the consumption of current from the line is from 1½ to 2 amperes. When alternating current is not available, a D.C.-A.C. converter can be furnished at low cost. This current is stepped up so that when delivered from the secondary of the transformer, there are 20 amperes of current at a potential of 2 volts available for marking. To provide for obtaining the desired depth of marking, a rheostat is furnished which provides for adjusting the amount of current delivered to the pencil of the etchograph. This pencil is used as an ordinary lead pencil would be handled, and provision may be made either for writing free hand script or for printing, according to the class of marking which may be desired. The etchograph is adapted for marking either iron or steel, and all classes of high-speed carbon and machine steel may be marked with equal facility, no matter whether it is in the hardened or soft condition.

Another apparatus known as the "electro-stylograph," which writes on metal, is shown in the accompanying illustration. In addition to its application in marking tools, this equipment may be employed to advantage for marking metallurgical test specimens, etc. Marking with the electro-stylograph is accomplished by utilizing the well-known principle of localized surface fusion produced by resistance to the flow of electric current of low voltage and high amperage from the stylus to the piece which is to be marked. The apparatus is designed in such a way that delicate control is afforded so that the writing may be varied from a fine hair line to about 1/16 inch in width. This control is so effective that thin steel instruments may be marked without danger of burning. The amount of current consumed is approximately the same as that required to operate an ordinary incandescent light. Connection is made with an ordinary electric light circuit of 110 volts and 60 cycles alternating current. A particular advantage of this general method of marking is that it does not set up any internal strains in the metal.



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