

Oct. 22, 1935.

F. J. BICKEL

2,018,435

PROFILING MACHINE

Filed May 12, 1933

4 Sheets-Sheet 1

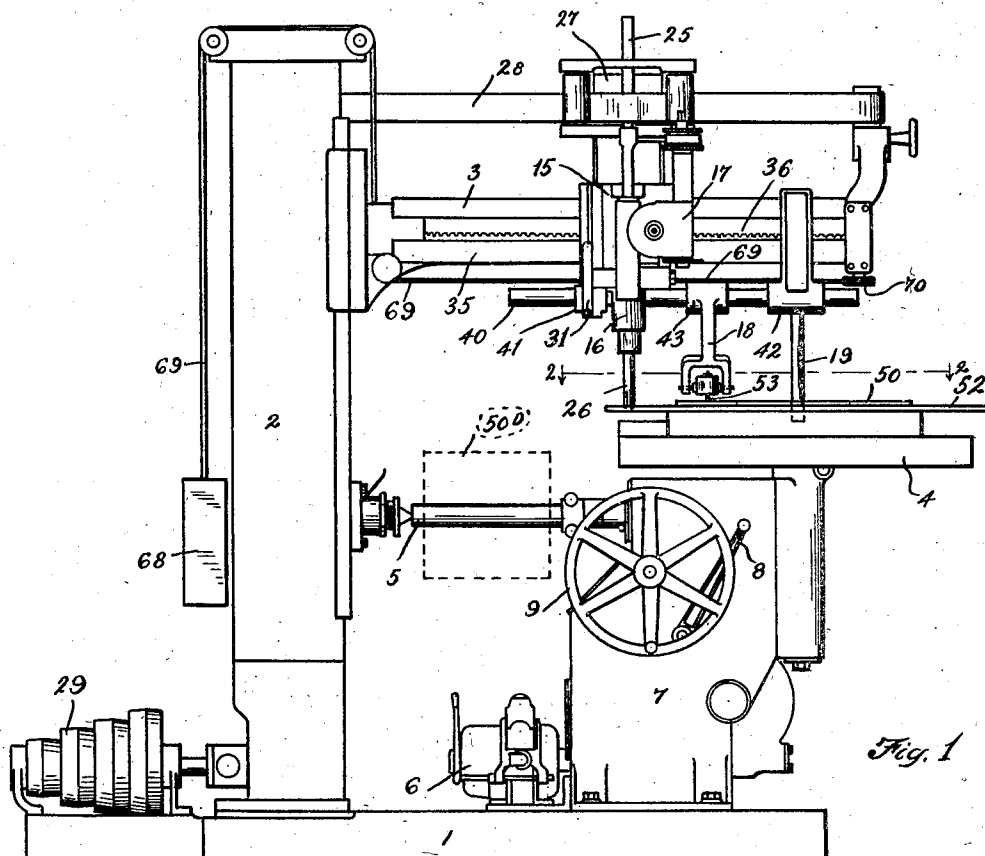


Fig. 1

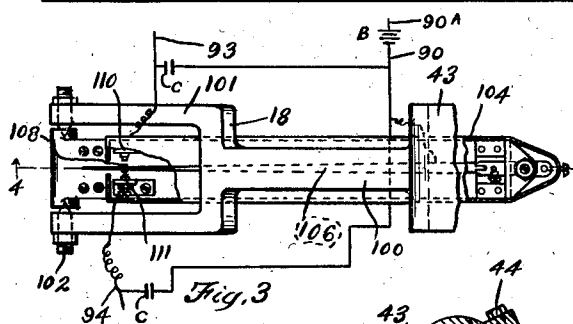


Fig. 3

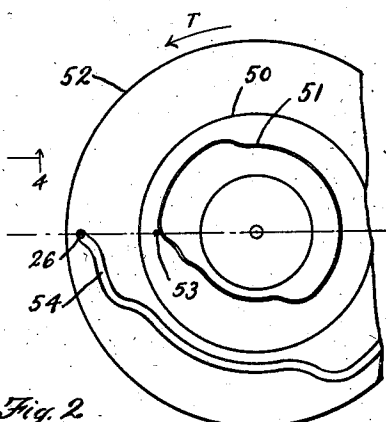


Fig. 2

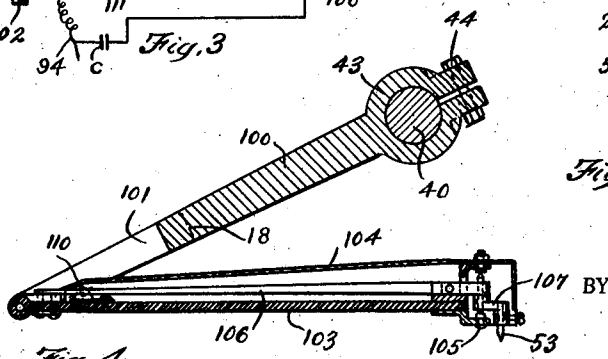


Fig. 4

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4 Sheets-Sheet 2

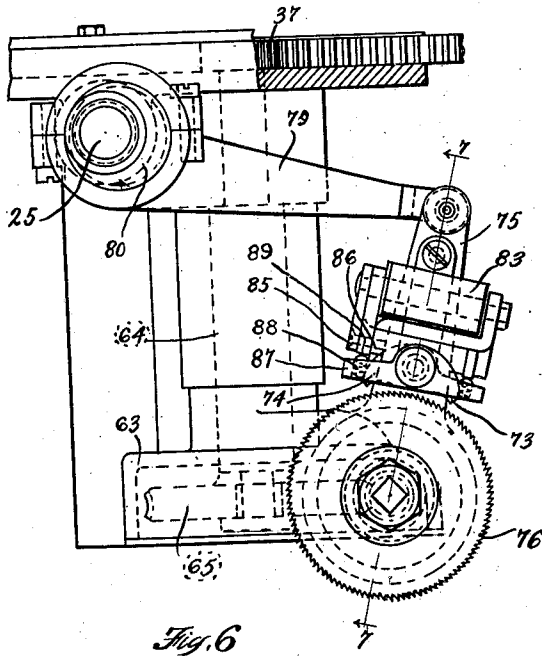


Fig. 6

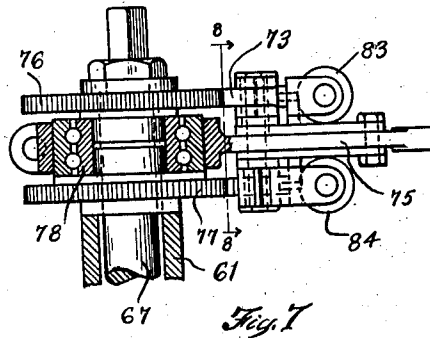


Fig. 7

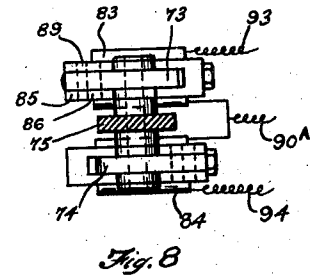


Fig. 8

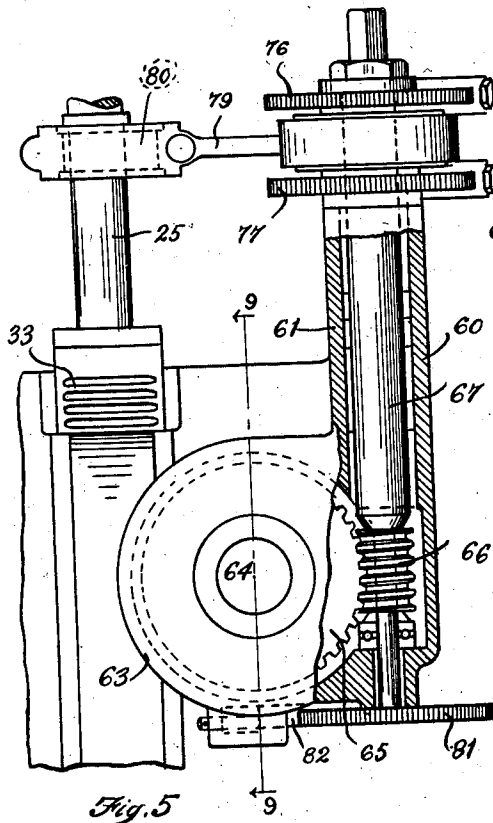


Fig. 5

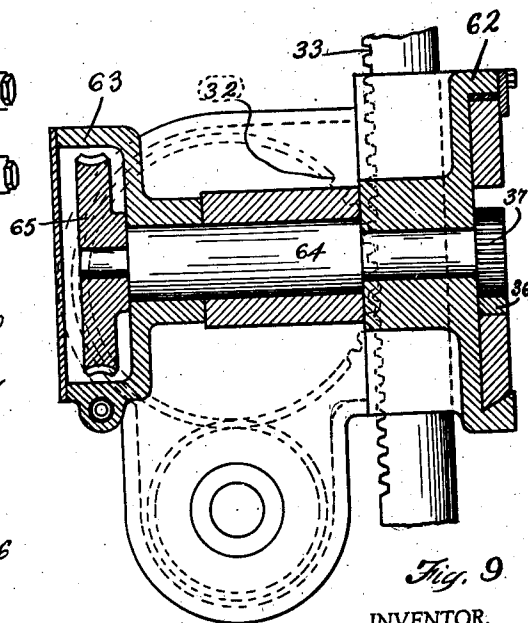


Fig. 9

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PROFILING MACHINE

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4 Sheets-Sheet 3

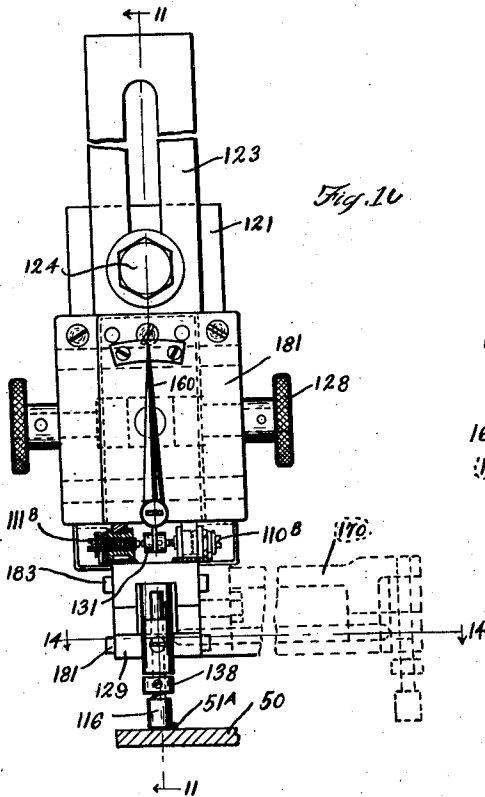


Fig. 10

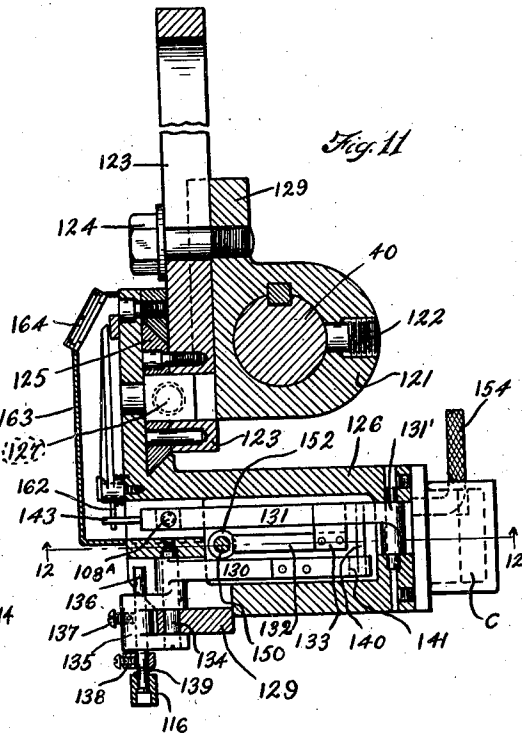


Fig. 11

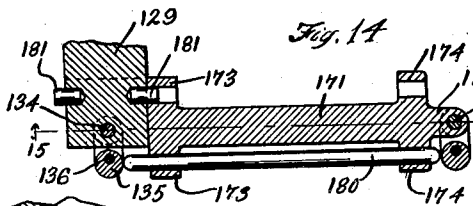


Fig. 14

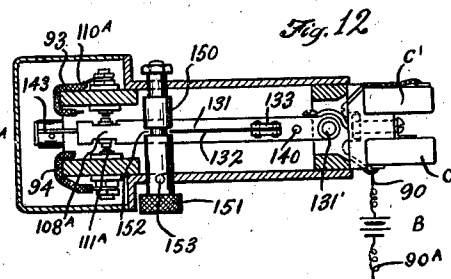


Fig. 12

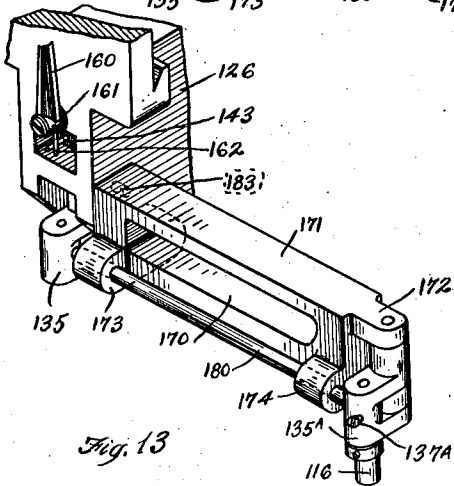


Fig. 13

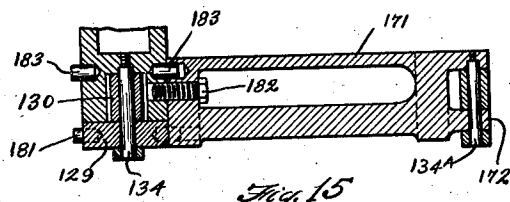


Fig. 15

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PROFILING MACHINE
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2,018,435

4 Sheets-Sheet 4

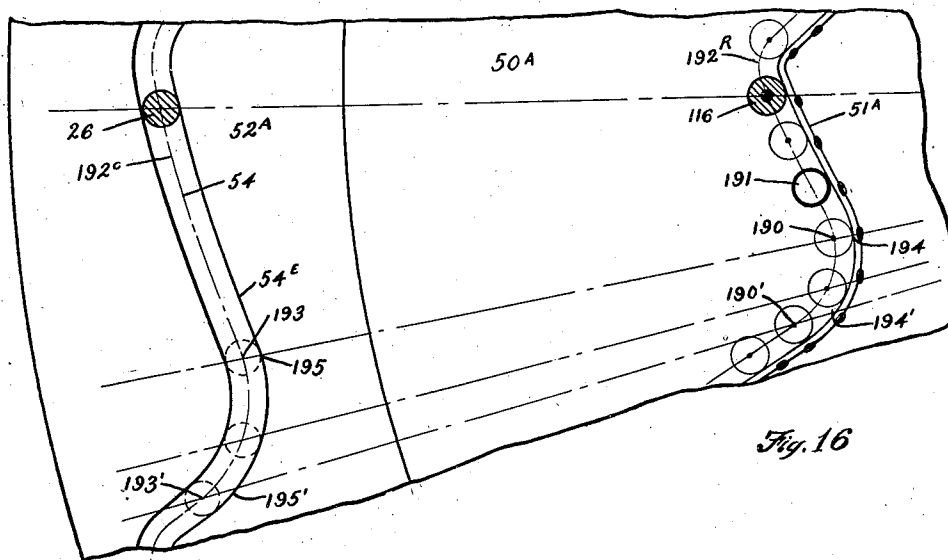


Fig. 16

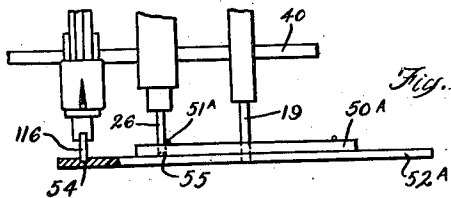


Fig. 17

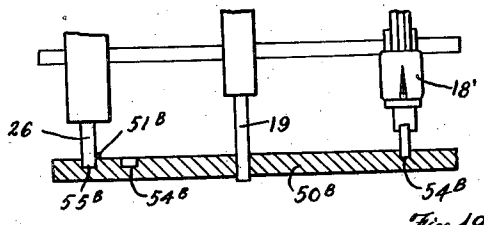


Fig. 18

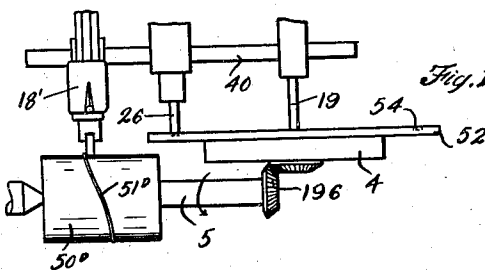


Fig. 19

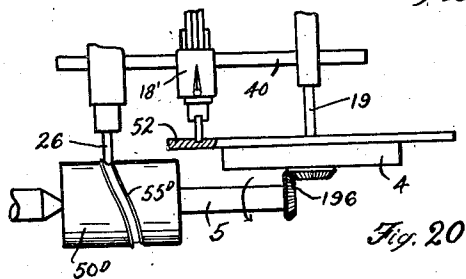


Fig. 20

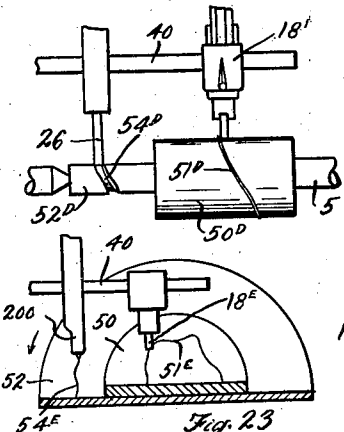


Fig. 21

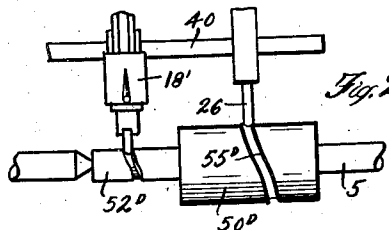


Fig. 22

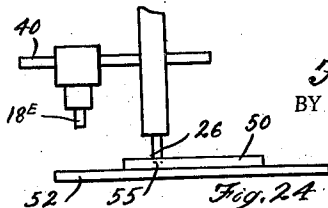


Fig. 23

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UNITED STATES PATENT OFFICE

2,018,435

PROFILING MACHINE

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land, Ohio, a corporation of Ohio

Application May 12, 1933, Serial No. 670,729

21 Claims. (Cl. 90—13.7)

This invention relates to a machine and method for cutting in an irregular path and is particularly directed to the problem of cutting cams for automatic machinery quickly, cheaply and accurately.

In making cams for automatic machinery where a number of different cams have to be made in order to satisfy special conditions of machine operation the cost of preparing the cams is sometimes almost prohibitive. For example such a situation occurs when an automatic machine has to be put through a special cycle for a comparatively small quantity of production and the cam used for the purpose may never be needed again. By my improved machine and method I am enabled, first to lay out the cam profile on the material which is to form the final cam, next to transfer this to a "master", and finally use the same machine in changed arrangement to cut the actual cam very accurately to the original layout line. The "master" is not strictly a templet, for, although it corresponds to the cam outline, it is preferably on a different scale and may not be of the same shape, although it must be of a shape from which the cam can be accurately reproduced. The machine and method can be used to produce various types of cams, such as disk or drum, peripheral or grooved, and modified forms, all as will be apparent from the following specification. The operation is automatic and relatively speedy and the degree of accuracy obtainable is higher than by any other method of which I am aware.

In its present preferred embodiment this invention is best exemplified in certain attachments for and methods of operating a milling machine of the vertical spindle type.

To the accomplishment of the foregoing and related ends, said invention, then, consists of the means hereinafter fully described and particularly pointed out in the claims, the annexed drawings and the following description setting forth in detail certain means and one mode of carrying out the invention, such disclosed means and mode illustrating, however, but one of various ways in which the principle of the invention may be used.

In the accompanying drawings Fig. 1 is a front elevation of a milling machine with my invention applied thereto; Fig. 2 is a partial plan view taken from Fig. 1 approximately on the line 2—2; Fig. 3 is a detailed plan of one form of the tracer unit of my invention; Fig. 4 is a sectional view of the same on the line 4—4 of Fig. 3; Fig. 5 is an enlarged detail from Fig. 1, partly in section, showing the means for traversing the

carriage on the rack; Fig. 6 is a top plan view of the mechanism of Fig. 5; Fig. 7 is a view on a vertical plane, partly in section and partly in elevation, approximately along the line 7—7 of Fig. 6; Fig. 8 is a detail partly in section and partly in elevation on the line 8—8 Fig. 7; Fig. 9 is a partial vertical section on the line 9—9 Fig. 5; Fig. 10 is a front elevation of a modified form of tracer unit; Fig. 11 is a central vertical section through Fig. 10 on the line 11—11; Fig. 12 is a horizontal section through Fig. 11 on the line 12—12, looking upwards; Fig. 13 is a perspective view of an attachment; Fig. 14 is a horizontal section through the attachment of Fig. 13, taken on the line 14—14 of Fig. 10; Fig. 15 is a vertical section on the line 15—15 of Fig. 14; Fig. 16 is an enlarged portion of a view which generally corresponds to Fig. 2; Figs. 17 to 22 inclusive are diagrammatic illustrations of various set-ups of the machine; Figs. 23 and 24 illustrate further modifications.

General arrangement

The general arrangement of the apparatus is shown in Fig. 1 wherein it is shown as applied to a vertical spindle milling machine, the machine being equipped with both vertical and horizontal turning axes. The machine comprises a base 1, standard 2, horizontal arm 3 vertically adjustable on the standard, a horizontal turntable 4 adapted to carry flat disks and a horizontal mandrel 5 adapted to receive cylindrical work. A motor 6 drives the table 4 or mandrel 5 or both through suitable reduction gears contained in a supporting base 7. As herein illustrated, the machine is provided with a control lever 8 for setting into operation either the table 4 or the mandrel 5 or both. A hand actuated wheel 9 is provided for use in turning the mechanism by hand, as in setting up the work, etc. A carriage generally indicated by the reference character 15 is movable along the arm 3. This carriage 15 carries a milling unit 16, a control unit 17, shown in detail on Sheet 2, and a tracer unit 18, one form of which is shown in Figs. 3 and 4, and another form of which is shown on Sheet 3. A center brace or steadying post 19 connects the horizontal table 4 with the arm 3 to give greater stiffness and accuracy to the mechanism.

The milling unit itself may be of standard construction and is here shown as a vertical spindle 25 carrying at its lower end a cutter bit 26 and driven by a pulley 27 taking power from a belt 28 driven by a suitable train of mechanism not shown, power preferably being applied to this

part of the machine through any one of the step pulleys 29. The cutter 26 may be raised and lowered in the usual way by means of a hand wheel 31, Fig. 1, which turns a pinion 32 travelling on a vertical rack 33, Figs. 5 and 9. It will be noted that the lower bar 35 of the horizontal arm 3 is fitted with a toothed rack 36 on its upper surface. The carriage 15 is moved and set along the horizontal arm 3 by the control unit 17 which drives a pinion 37, Fig. 9, along the rack 36 as more fully explained in the detailed description of the control unit, below. The lower part of the carriage 15 carries a horizontal bar 40 in a suitable clamping arrangement such as that indicated in a general way by the sleeve 41. This bar may also be conveniently guided through a sleeve 42 on the center brace 19. The tracer unit 18 is clamped to the bar 40 in any suitable manner, as by the split sleeve 43 which can be clamped by the bolts 44, Fig. 4. Thus, movement of the carriage 15 along the arm 3 moves the tracer unit 18 as well as the milling unit 16, without changing the mutual relationship between these two.

The operation, in general terms, is that a cam plate such as 50 is placed on the machine where it is to be used, and a cam layout, such as 51, Fig. 2, is outlined thereon by any suitable means. The cam blank 50 is superposed on a templet or master blank 52 on the table 4 and both are secured to the table 4 to rotate therewith. A follower 53, which is part of the tracer unit, is set to follow the layout line 51. As this follower moves to accommodate itself to the formations in the layout line it actuates suitable mechanism to cause the control unit 17 to move the carriage 15 back and forth along the horizontal arm 3, thus causing the cutter 26 to follow a course 54, concentric with the line 51. In the present illustrative embodiment, as shown in Fig. 2, the direction of the table 4, seen from above, is counter-clockwise, as indicated by the arrow T. With the set-up shown in Fig. 1, the cutter path 54 is a groove; with a deeper setting of the cutter 26 that portion of the master which is outside the cutter path 54 could be cut off entirely.

After the master has been cut the tracer unit 18 is moved to another position on the rod 40, so that the follower 53 will run in the master path 54 and the cutter 26 will cut the cam 50 along the original line 51. Fig. 17 shows this second stage, cutting a groove 55 in the cam plate 50, thus making a face cam. A disk cam would be made by a deeper setting of the cutter 26, removing the outer part of the plate 50. Various modifications of the steps just described are possible, and some of these will be explained under the heading "Operation".

Control unit

The control unit, generally indicated at 17 in Fig. 1, is illustrated in detail in Figs. 5 to 9 inclusive. It comprises a frame generally designated as 60 which is rigidly connected to, and may form part of, the structure of the carriage 15. In detail this frame 60 comprises an upright tubular member 61 and a gear case 63. A horizontal shaft 64 journaled at one end in the back of the gear case 63 and at the other end in the saddle 62 has fixed upon its one end a worm wheel 65 driven by a worm 66 upon the lower end of a vertical shaft 67, and at its other end the pinion 37, previously mentioned, which meshes with and moves along the rack 36. The top of the shaft 67 is squared to receive a tool,

movable by hand in exceptional instances, such as setting the machine, etc. Since a high degree of accuracy is one of the features of the present invention, some means for preventing backlash between the pinion and rack is desirable. A convenient arrangement is shown in Fig. 1 where a weight 68 is suspended by a cable 69. This cable, passing over a series of pulleys, the last of which, 70, on the far end of the arm 3, reverses the direction of pull, is attached to the carriage 15 so as to create a constant outward pull on the carriage, thus keeping the teeth of the pinion 37 tight in one direction against those of the rack 36.

The shaft 67, Fig. 5, carried by suitable bearings in the upright 61, is revolved in either direction in response to the movements of the follower 53, Fig. 1.

Although this responsive movement may be accomplished by the use of any suitable mechanism which will give a sufficient degree of accuracy, I prefer to employ a pair of oppositely directed pawls 73 and 74 carried upon a vibrating arm 75 and adapted to engage corresponding ratchet wheels 76 and 77 respectively, these wheels being fast to the upper end of the shaft 67. This arm 75 is pivoted as indicated at 78, Fig. 7, concentrically upon the upper end of the shaft 67, and in the present instance is actuated or vibrated by a link 79 moved by an eccentric 80 on the upper part of the shaft 25, though other suitable means may be employed. These details of connection are omitted from Fig. 1 to avoid confusion. Rotation of the shaft 67 except by the pawls is prevented by a notched disk 81 on the bottom of the shaft, and a detent 82 engaging the notches.

The preferred means of actuating the pawls is by electromagnets 83 and 84, each having its two poles brought together near one end as at 85 and 86 in the case of the upper magnet. The tail 87 of the upper pawl 73 is attracted when this magnet is energized, thus bringing the point of the pawl against one of the ratchet teeth of the wheel 76. A button actuated by a spring 88 and bearing against a piece of non-magnetic material 89 between the pole pieces 85 and 86 throws the pawl out of engagement when the circuit is broken. The magnet 84 and pawl 74 are correspondingly arranged, but of course in reversed direction, and the teeth of the lower wheel 77 point oppositely to those of the upper wheel 76. The wiring of the magnets is indicated diagrammatically in Fig. 8, the wires being similarly numbered at the tracer unit, Fig. 3. As will be described hereafter, the magnets are operated by the tracer unit, which unit will now be described in detail.

Tracer unit

The tracer unit is generally indicated by the reference character 18, Fig. 1. Such a unit is shown in its simplest form in Figs. 3 and 4. Another form, preferably for certain classes of work, is illustrated on Sheet 3, Figs. 10 to 15 inclusive. The form shown in Figs. 3 and 4 comprises a supporting arm 100, forked at its lower end as at 101 and adapted to be fastened by the clamp 43 at its upper end to the rod 40. Pivots such as 102 carried by the fork support one end of a plate 103 of non-conducting material which will hereafter be termed the "tracer plate". This plate, which may conveniently be covered by a protective housing 104, carries at its free end a pair of vertical bearings 105 between which a

feeler arm 106, forming part of the electric control circuits, is pivoted. This arm includes a relatively very short forward extension 107 carrying the needle 53 or some equivalent follower member. In the remainder of the description the term "follower" is used in a somewhat general sense to refer either to this needle or to a member having similar functions. Various forms of followers are described below.

The movement of the rear end of the arm 106, which carries a double contact point 108, is limited by opposite horizontally disposed contacts 110 and 111, with one of which the point 108 contacts as the arm 106 swings. A wire 90 from one side of any suitable source of power, such as a battery B, is connected with the arm 106 in any convenient manner. A wire 90A from the other side of B is common to both magnet circuits, as shown in Fig. 8. Condensers C are bridged across the contacts 108—110 and 108—111 to reduce arcing. The wires 93 and 94 are respectively connected to the contact points 110 and 111. By comparing Fig. 3 with Fig. 8, since the corresponding wires of the magnet circuits bear the same numbers in each figure, it will be seen that movement of the follower toward the bottom of the page (to the left in Fig. 2) will energize the upper magnet 83 and thus move the cutter 26 to the left. The cutter carries with it the rod 40 and thus moves the tracer unit 18 to the left, causing the follower to resume its central position, which moves the arm 106, thus opening both control circuits and leaving both magnets inoperative.

Since the tracer unit is made responsive to very close variations in the layout 51 or templet path 54, on the order of .001 inch, suitable adjusting means are provided, of well-known character, not described in detail.

Figs. 10 to 15 inclusive illustrate a modified follower, generally designated as 18'. As illustrated, this modified form is equipped with a roller 116 instead of a needle point. It would also be within the purview of the invention to use a needle point on the form shown in Fig. 10 or to use a roller on the form shown in Figs. 3 and 4. Under some conditions a roller such as 116 has a tendency to climb and it may be advisable to employ a non-rotating member. There is some discussion below of the relative diameters of the roller 116 and the cutting tool 26. Where pertinent it will be understood that if a finger is used instead of a roller, the finger will be of such size as to cause the elements in tracing their various paths to conform as to center lines, etc., all of which will be readily understood as the description proceeds. This matter will be further discussed under the heading "Operation".

The modified follower comprises an anchor bracket 121 keyed upon the rod 40 and capable of being fastened at any position thereon by a set screw 122. A vertical adjusting slide 123 is movable up and down on the anchor bracket and can be locked in position by a screw 124. A body retaining slide 125 is carried by the lower end of the vertical adjusting slide, and the tracer unit body 126 is horizontally movable thereon by a threaded shaft 127 having thumb nuts 128 at each end. The body 126 houses and supports the tracer mechanism. This mechanism consists of two superposed levers 130 and 131, also called respectively the tracer pin carrier arm and the contact point carrier arm. The lower lever 130 is of the first order, having a fulcrum 134 between the short front arm 135 and the long rear

arm. The upper lever 131 has its fulcrum 131' at one end, slightly beyond the free end of the long arm of the lower lever. The lower lever fulcrum 134 passes through a plate 129 secured to the lower forward portion of the body 126, and its upper end is fastened into a part of the body 126. The arm 135 of the lower lever carries a roller 116 upon the lower end of a tracer roller pin 136, with appropriate details, such as the set screw 137 for vertical adjustment, and a collar 138 adjustably secured upon the pin 136 and holding down a short coiled spring 139 which bears down upon the roller 116, holding the roller axially against the enlarged lower end of the pin 136, as will be seen in Fig. 11. A vertical pin 140 secured in and depending from the contact point arm 131 near its fulcrum, is engaged at its lower end between the two sides of a fork 141 within the free end of the long arm of the tracer pin carrier 130, transmits the motion of the lower lever to the upper. This arrangement will be readily seen as one by which the motion of the roller 116 is greatly magnified. The free end of the arm 131 carries a double contact point 108A, part of the magnet control circuit, and also a horizontally projecting pin 143 which actuates a visual indicator.

By an arrangement seen in Fig. 12 the lever system can be left free to respond to movements of the roller 116 in either direction or can be selectively urged toward one side or the other. This is accomplished by means of a tension spring 132 and a tension spring lock 150. The spring is a flat leaf rigidly bracketed at 133 to the contact point arm 131 and extending parallel to and below that arm in the direction away from the fulcrum 131'.

The lock consists of a rod disposed transversely across the tracer lever housing and capable of a limited axial movement. This rod has a knurled head or thumb piece 151 at one end, is reduced in diameter at the other end for a length not less than its allowable travel, and is also annularly grooved at 152 at its mid length. A radial pin 153 is fixed in the rod near the thumb piece 151. The lock 150 is rotated and the radial pin 153 engages with suitable stops (not shown), when the rod is rotated, to hold the rod in any one of three positions against axial movement. The position illustrated in Fig. 12 is neutral and leaves the lever system free to move in either direction according to the movements of the roller 116. When the thumb piece 151 of the lock 150 is moved toward the tracer unit housing and the lock turned to engage the pin 153 against its stop (which may be the inner wall of the housing), the corresponding shoulder of the groove 152 is brought to bear against the free end of the spring 132 and the arm 131 is thus given a constant tendency clockwise (as seen in Fig. 12) about its fulcrum. This in turn moves the roller 116 in the opposite direction and causes it to bear constantly against its guiding surface, such as the wire 51A in Fig. 10. This wire 51A, to be described in more detail below, serves the same purpose as the groove 51. If the guiding surface were on the other side of the roller 116 the tension spring lock would be moved and set in the opposite sense.

The electrical system is, in general similar to that of Figs. 3 and 4 and the same reference characters will be used to designate the various wires, since these wires perform the same functions in the circuit and the connections to the magnets in Figs. 6, 7 and 8 are precisely the same. The

wiring is somewhat more compact than that indicated in Figs. 3 and 4, all of the leads to and from the tracer unit housing being combined in a cable 154. The circuit includes a source of power such as the battery B, connected by the conductors 90 and 90A to the upper lever 131 and to the magnets, Fig. 8, respectively. Condensers C' are bridged across the contact points 108A—110A and 108A—111A. The double contact point 108A completes the circuit through the contact 110A or 111A, as the case may be. From the contact 110A a wire 93 leads to the magnet 83 and from the contact 111A a wire 94 leads to the magnet 84. (See Figs. 12 and 8.) The contact points are adjustable by any suitable means, that shown being by having them mounted on the inner ends of screws 110B and 111B respectively (Fig. 10) these screws passing through the centers of the binding posts.

Besides the electrical control, a visual indicator is provided consisting of a needle 160 on the face of the tracer unit body. This needle is pivoted at its bottom and is given a constant clockwise tendency (Fig. 10) by any convenient arrangement, such as the coiled spring 161. A pin 162, fixed to and projecting down from the needle, is thus kept in constant contact with the pin 143. A cover 163, windowed at 164, protects the indicator. This cover is omitted in Fig. 10 so as not to conceal the mechanism.

In certain situations it is necessary to work with the follower very close to the cutter 26 or to the center brace 19 it being sometimes desirable that this approach be less than body clearance. To take care of such a situation an extension 170 may be used on either side of the tracer unit. This extension is shown in Figs. 13, 14 and 15 and its application is indicated by dotted lines in Fig. 10.

This extension comprises an arm 171 with a flat end which can bear accurately against either side of the body 126 and with a bracket 172 on its other end, which will be designated as the free end.

This bracket carries a short arm 135A pivoted upon the pin 134A, these parts being analogous to the parts 135 and 134. A set screw 137A in the arm 135A holds the pin 136, which, with its roller 116 and various other elements, is removed from the lever arm 135 and inserted in 135A when the extension is used. Ears 173 and 174 on each end and each side of the arm 171 are apertured longitudinally for two purposes. As will be apparent from inspection of Fig. 14, the apertures on one side serve as guide bearings for a push rod 180 which transmits thrust from the lever arm 135A to the lever arm 135. The aperture in the other ear 173 fits over a dowel pin 181 in the side of the tracer unit body. This dowel pin and the adjoining flat surfaces of the plate 129 on the bottom of the body and at the end of the arm 171 position the arm 171 very accurately. A cap screw such as 182 (Fig. 15) holds the arm 171 in position. There is also an upper dowel pin 183 which fits in an appropriate recess higher on the end of the extension arm. The dowel pins just mentioned are duplicated on the other side of the tracer unit body. Thus, by reversing the end of the extension arm and putting the rod 180 through the apertures on the opposite side, the extension may point in a direction opposite to that shown.

It is within the scope of the invention to use other tracer units. For example, a photoelectric cell following a line of contrasting light value

might be used in place of either of the tracer units which have been described above.

Operation

As already mentioned, the usual mode of operation is that during the first revolution of the table 4 the follower 53 or 116 follows the layout line on the cam and the cutter 26 forms a path on the master; during the second revolution the follower follows the master path and the cutter cuts to the layout line on the cam. Thus the first cam is formed in two complete revolutions of the table, and subsequent cams are formed in one revolution. Theoretically, if the cam layout were a circle concentric with the table center, the tracer unit would never move during the entire revolution, the magnets 73 and 74 would never be energized, and the carriage 15 would never move along the arm 3. In practice some corrective movement would be given even in concentric circular work, since no machine of this sort can be expected to run with theoretical perfection. Of course the tracer and control units are in continual action whenever working on non-circular or non-concentric parts of the cam. The detailed operation of the control unit 17 has already been described and will not be further mentioned except to point out that when the upper magnet 83 is energized and its pawl is engaged with the wheel 76, the arcuate swing of the arm 75 turns the shaft 67 clockwise (Fig. 6) thus turning the worm wheel 65, horizontal shaft 64 and pinion 37 counter-clockwise and so moving the carriage 15, which, it will be remembered, carries the rod 40 with cutter and tracer unit, to the left (Fig. 1). This movement besides correcting the position of the cutter 26, so positions the tracer plate with respect to the layout line that the arm 106 can swing to its central position. The action of the lower magnet 84 is just the reverse. The weight 68 or some other suitable arrangement prevents any backlash or looseness between the pinion 37 and the rack 36, so that movements as small as .001 inch are accurately made.

The rate of vibration of the arm 75 is relatively rapid while the turning of the table 4 (and of the shaft 5 when working on drums) is relatively very slow. For this reason the fact that the shafts 67 and 64 take an intermittent instead of a steady movement is negligible in effect, introducing an error which is within the limits of tolerance in the final product. It would be within the scope of the invention to use suitable mechanism to apply the corrective movement continuously, but the arrangement shown in Fig. 2 has given satisfactory results, and so far has been superior in accuracy to any continuous movement means. It will be understood that by continuous movement I mean a movement that would be continuous only so long as the follower was away from its central position.

A number of different arrangements of cam, master, cutter unit and tracer unit are possible. That illustrated in Figs. 1 and 2 has already been described under the heading "General arrangement" and will be taken as standard for purposes of comparison although in reality no particular set-up is more standard than any other. The one most appropriate to the work in hand will be used in each instance.

Several variations are illustrated in diagrammatic style on Sheet 4, Figs. 16 to 22 inclusive, and will be described briefly. So far as possible the same reference characters as in Figs. 1 and 2

will be used, distinguished by letters or primes.

In using a roller follower such as 116 it is necessary for highly accurate work to have the roller of the same diameter as the width of the finished cam groove. The diameter of the cutter for the master is immaterial but when the tracer unit is following the master, the follower 116 must have the same diameter as the cutter with which the master was cut. This is explained in connection with Fig. 16. As Fig. 16 shows, the layout on the cam plate 50A may be a wire 51A instead of a groove. This wire will define what will ultimately become one edge of the cam plate, for a disk cam, or one edge of the cam groove for a face cam. A convenient way of locating the wire is to lay out the cam path by a series of center punch marks such as 190 offset from the edge line a distance equal to the cutter radius, place on the punch marks successively a button such as 191 of the cutter diameter and having a center point fitting the punch marks, then bend the wire 51A in a smooth curve tangent to the button as it is moved from one position to the next and tack-solder the wire in position. The wire is shown as inside, that is, toward the center of the plate 50A, but it might equally well be laid outside. Then as the cam plate 50A is rotated, the center of the roller 116 will follow the path 192R, and the center of the cutter bit 26 will follow the corresponding path 192C. Since the bit and roller for the cam are of equal diameter, and the bit and roller for the master are of equal diameter, the sides of the master groove 54 (or its edge 54E if the cut is entirely through the master) will correspond to the position of the wire 51A, with the result that when the cutters and rollers are interchanged for position the groove edge (or the face, as the case may be) of the cam as finally cut will be exactly as was originally defined by the wire. This condition will obtain throughout workable ranges of sharp and irregular curves.

By way of explanation, if 193 be taken as the center of the cutter position corresponding to roller center position 190, and 193' be the position corresponding to another roller center position 190', it will be seen that the distance 193—190 equals 193'—190', because for any particular job the cutter unit and tracer unit are always fixed on the bar 40. But if each of the lines 193—190 and 193'—190' be projected to intersect 51A at 194 and 194', respectively, the distance 193—194 will be less than 193'—194'. Also, calling the intersections with the edge 54E 194 and 195' respectively, 194—195 is shorter than 194'—195'. The only series of points constantly spaced, and therefore interchangeable, are paths 192R and 192C, of the tracer center and cutter center.

In Fig. 17 the tracer unit is shown with its roller 116 running in a groove 54 in the master 52A while the cutter 26 is milling a face cam groove 55 in the cam plate 50A. The wire 51A is shown here to indicate the relative positions. It might be removed either before or after the cam is completed.

Another arrangement is that of Fig. 18 wherein the cutter 26 and tracer 18' are on opposite sides of the center brace 19. Here only a single piece 50B is used for both master and cam. On the first revolution (not illustrated) the tracer follows the wire 51B and the cutter 26 cuts the master groove 54B. On the second revolution, illustrated, the tracer follows the groove 54B and the cutter cuts the final cam groove 55B. This of

course leaves the master groove in the completed cam, which is not usually objectionable. It is an economical method where only one cam is to be cut and the cam track is fairly well spaced from the center 19.

Figs. 19 and 20 illustrate diagrammatically a set-up for cutting a drum cam, using a flat master. The direction of rotation is indicated by the arrow. A pair of bevel gears 196 are shown to indicate diagrammatically that the drum 10 shaft 5 and table 4 rotate synchronously. In Fig. 19 the drum 50D is shown with the layout line 51D thereon with the tracer 18' following this line. The cutter 26 is forming the master 52 as in Figs. 1 and 2. In Fig. 20 the master 52 has been formed and the follower 18' is following its edge while the cutter 26 cuts the final cam path 54D in the drum.

A further modification is shown in Figs. 21 and 22, wherein the master is also drum-shaped 20 and mounted co-axially with the cam drum 50D on the shaft 5. As with the flat forms, the relative sizes of master and cam drum may vary. In the present example the master is smaller in diameter. The principles of operation are the same. As seen in Fig. 21 the layout line 51D on the cam drum 50D is followed by the tracer 18', which governs the movement of the cutter 26 forming the groove 54D on the master 52D. Cutter and tracer are then reversed, as shown 30 in Fig. 22, and the final cam groove 55D is cut on the cam drum 50D.

A further modification is shown in Figs. 23 and 24. Here the cam layout line 51E is marked on the cam blank in a contrasting color and is followed by a photoelectric cell 18E instead of by a needle or a roller. On the first revolution the cutter is replaced on the bar 40 by a marking mechanism 200 (for example, a recording pen), which marks a master path 54E on suitable material, such as a sheet of cardboard. For the second, cam forming, revolution the photoelectric cell 18E is positioned to follow the master line 54E and a cutter 26 as in Fig. 2 is used to cut the final cam path 55. This method is of course susceptible of various modifications along the lines already suggested, such as combinations of flat elements and drum elements, the use of grooves instead of colored lines, needles instead of the elements 200 and 18E, and so on. 50

Under certain circumstances it may be advisable to use the machine for only a part of the complete process. For example, in instances where it is possible to lay out the cam on a scale larger or smaller than actual size, the layout line can be scribed, wired, or otherwise formed by hand on the master blank; the master and cam blank are then placed on the machine and the cam cut in one revolution, running the follower on the layout line while the cutter cuts the cam. In other situations it may be desirable to produce the completed master alone as an article of manufacture. All such specialized adaptations of the invention to particular conditions are within the scope of the invention. 65

The invention, several examples of which have been described in detail, thus comprises methods and means whereby a delicate guide, requiring very little power for its operation, positions a cutter which must be strongly held and strongly driven. In the most usual cycle of operations this guiding and cutting relationship will be used first to transfer the cam layout line to a permanently projected form on solid material, and next to use this projected form as a guide for 75

cutting back to or through the layout line, in certain instances destroying the layout line by this final cut. For specialized conditions certain steps of the process may be changed in sequence, or omitted.

Although several possible arrangements have been shown it will be understood that all of these are intended more particularly to illustrate principles than to show all detailed possibilities.

Many other variations of the principles will suggest themselves, being characterized by having the master and the cam rotatable in some definite relationship and the path-following unit and path-tracing unit movable on both master and cam in some definite relationship to master and cam and to one another.

Other modes of applying the principle of my invention may be employed instead of the one explained, change being made as regards the means and the steps herein disclosed, provided those stated by any of the following claims or their equivalent be employed.

I therefore particularly point out and distinctly claim as my invention.

1. In a profiling machine a tracer unit, a follower supported thereby, adapted to follow a pattern, a movable support for said follower, stop means on said tracer limiting the follower movement, a path-making element in predetermined spaced relation to said tracer unit, and means for causing said follower support and said path-making element to move under the guidance of the movements of the follower.

2. In a profiling machine a tracer unit, a follower supported thereby, adapted to follow a pattern, a movable support for said follower, stop means on said tracer limiting the follower movement, a path-making element in constant spaced relation to said tracer unit, and means for causing said follower support and said path-making element to move in unison in conformity to the movements of the follower.

3. In a profiling machine a tracer unit, a follower supported thereby, adapted to follow a pattern, a movable support for said follower, stop means on said tracer limiting the follower movement, a path-making element in constant longitudinal spaced relation to said tracer unit, and means for causing said follower support and said path-making element to move in unison in conformity to the movements of the follower.

4. In a profiling machine, a rotatable work support, a work piece supported thereon, a pattern outline on said work piece, a follower adapted to follow said pattern outline on the work, a carrier for said follower whereon said follower is mounted for limited independent movement in response to variations of said pattern outline, a cutter at fixed radial distance from said follower carrier, a common support means for said follower carrier and for said cutter, and means for moving said common support means in conformity to the variations of said outline to restore said follower to predetermined position upon the follower carrier.

5. In a profiling machine in combination a revolving table, a cam pattern fixed to said table, a member to be cut revolving in synchronism with said table, a rod disposed above said table and above said member to be cut, said rod being radially disposed to said table, a cutter fixed to said rod and a control mechanism element adapted to respond to variations of the pattern with respect to itself and to move said rod in response thereto.

6. In a profiling machine in combination, a revolving table, a longitudinal rod thereabove, a cam pattern fixed to said table, a member to be cut fixed to said table, a cutter fixed to said rod and a control mechanism element also fixed to said rod and adapted to vary from a normal position in response to variations of the pattern and by such variation to apply power to move said rod to restore the control mechanism element to normal position and thereby move said cutter according to the pattern.

7. In a machine of the class described, a work rotating element, a tracer and a cutter, a mounting whereby said tracer and cutter are maintained in constant mutual relationship to the progress of the work, means for moving said tracer and cutter with respect to a path on the work.

8. In an apparatus of the class described, in sub-combination, a tracer unit extension comprising an arm adapted to be rigidly secured to either side of the tracer unit, a lever carried by said extension, a follower carried by said lever, and an extension rod adapted to transmit motion from said lever to the lever mechanism of said tracer unit.

9. In an apparatus of the class described, a work carrier, a tracer unit including a path following element, a path-forming unit, a bar rigidly supporting and joining said units, a carriage whereon said bar is mounted said carriage being movable with respect to the work carrier, and a side extension on said tracer unit parallel to said bar and carrying said path-following element.

10. That method of producing cams which comprises outlining the cam on the element which is to form the completed cam, using said outline to position cutting means in conformity thereto and spaced therefrom while cutting a guide surface, then using said last-named surface as a guide for operating said cutting means in spaced constant relation thereto while said cutter forms the cam surface.

11. That method of producing cams which comprises outlining the cam on the element which is to form the completed cam, using said outline to position cutting means in conformity thereto and spaced therefrom while cutting a guide surface upon another element, then using said last-named surface as a guide for operating said cutting means in spaced constant relation thereto while said cutter forms the cam surface upon said first-named element.

12. That method of producing cams which comprises outlining the cam on the element which is to form the completed cam, cutting a guide surface in constant relation to said outline, and then using said surface as a guide while cutting the cam.

13. A cam forming method which comprises laying out a cam on a blank, using the layout line as a guide to form a master path on the same blank, then using the master path as a guide for cutting the cam path on the original layout line.

14. That method of producing cams which comprises defining a master path on a blank, then moving said blank while cutting a path thereon, said cutting being guided from said master path.

15. The process of forming a cam by marking on a blank a series of central points for the cam path, offsetting equally from those points a flexible element, forming said element to a smooth curve and securing said element to the blank.

moving the blank while following said element with a follower of such size that as the follower bears against the element the center of the follower goes over the central points, at the same time cutting a path removed from the element.

16. In a mechanism of the class described, in combination, a carriage, means for moving said carriage in a straight line, a cutter unit carried by said carriage, a tracer unit carried by said carriage, said tracer unit including a follower, electrical controls adapted for operation by said follower and governing the movement of said carriage, and means operatively adjacent said carriage for rotating a work piece and a pattern.

17. In a mechanism of the class described, in combination, a carriage, means for moving said carriage in a straight line, a cutter unit carried by said carriage, a cutter included in said cutter unit, a tracer unit carried by said carriage, said tracer unit including a follower, electrical controls adapted for operation by said follower and governing the movement of said carriage, and means operatively adjacent said carriage for rotating a work piece and a pattern, said cutter, said follower, the line of movement of said carrier and radii of work piece and of pattern all lying in the same plane.

18. In a mechanism of the class described, in combination, a work moving unit, a tracer unit and a path forming unit, a carriage supporting both said units in operative relation to the work moving unit and in fixed relation to one another, a follower upon said tracer unit, means for moving said carriage under guidance of said follower, said tracer unit and said cutter unit being interchangeable upon said carriage, whereby a pattern path may be generated by said cutter in response to the action of said follower along

a layout line, and a cam surface may be generated along said layout line following the movement of said follower in said pattern.

19. In a machine of the class described, in combination, a carriage, a cutter and a tracer mounted thereon, work and pattern rotating means operatively adjacent thereto, mechanical means for moving said carriage with relation to said work and pattern rotating means, a follower upon said tracer unit adapted for coaction with a path on said work and pattern carrying means, and electrical means governed by said follower for selectively connecting said mechanical means in either direction with said carriage or for putting the same out of engagement.

20. In a machine of the class described, a source of power impulses independent of the direct guiding means, means for receiving relatively weak direct movements from a guide element and for transmitting power impulses from said source corresponding to such movements, path-making means directed and driven by said source, and means for moving said path-making means by said power impulses correspondingly to said direct movements.

21. In a machine of the class described, means for moving a pattern and work in predetermined time and distance relation, sensitive pattern-following means, insensitive pattern-following means carrying said sensitive means, path-forming means in fixed relation to said insensitive means, a common mounting for said insensitive means and said path-forming means, power means for shifting said mounting, and a control element for said power means actuated by said sensitive means.

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