

May 29, 1956

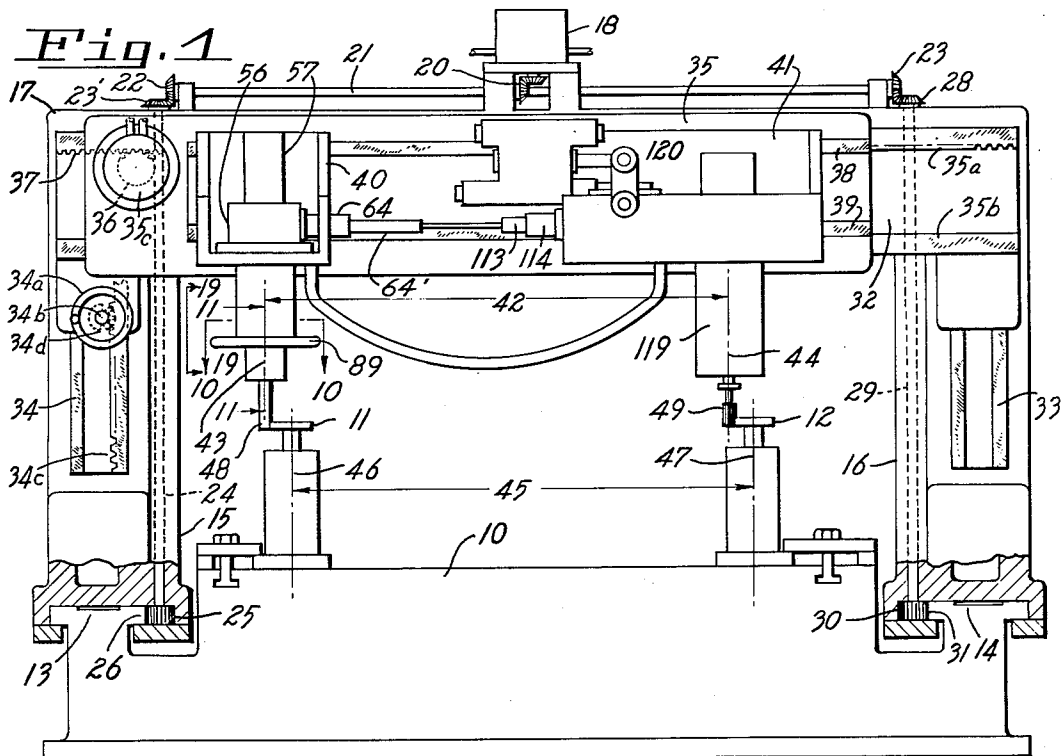
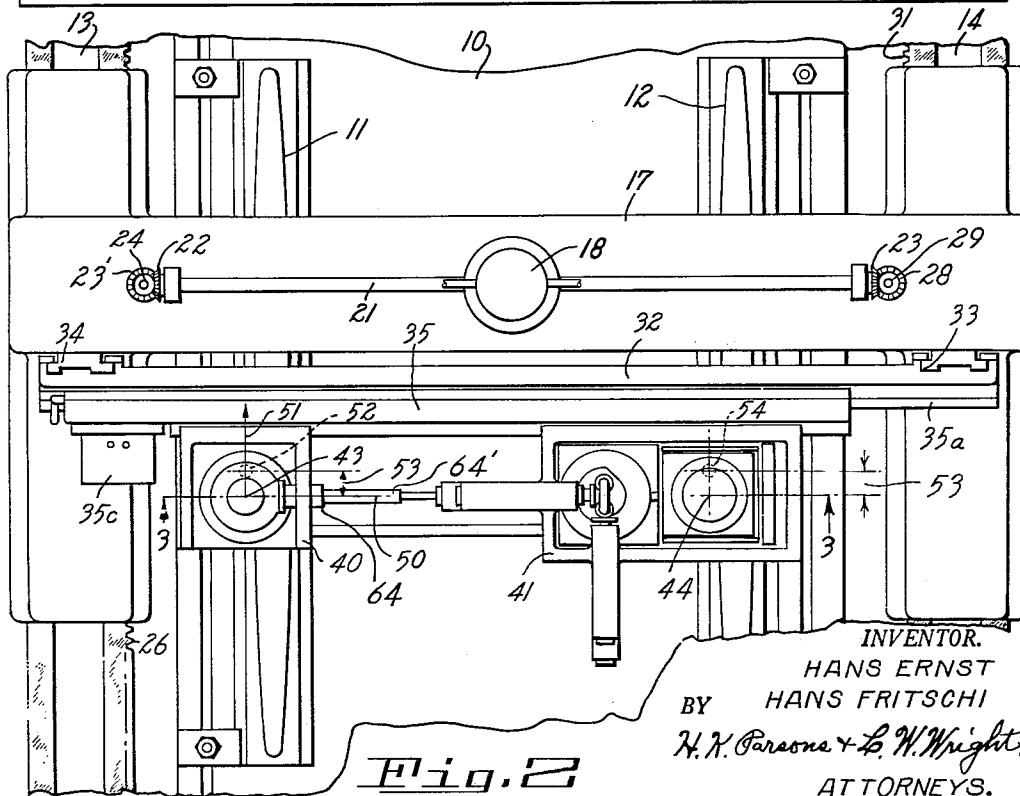
H. ERNST ET AL

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CUTTER POSITION COMPENSATING MECHANISM FOR PROFILING MACHINES

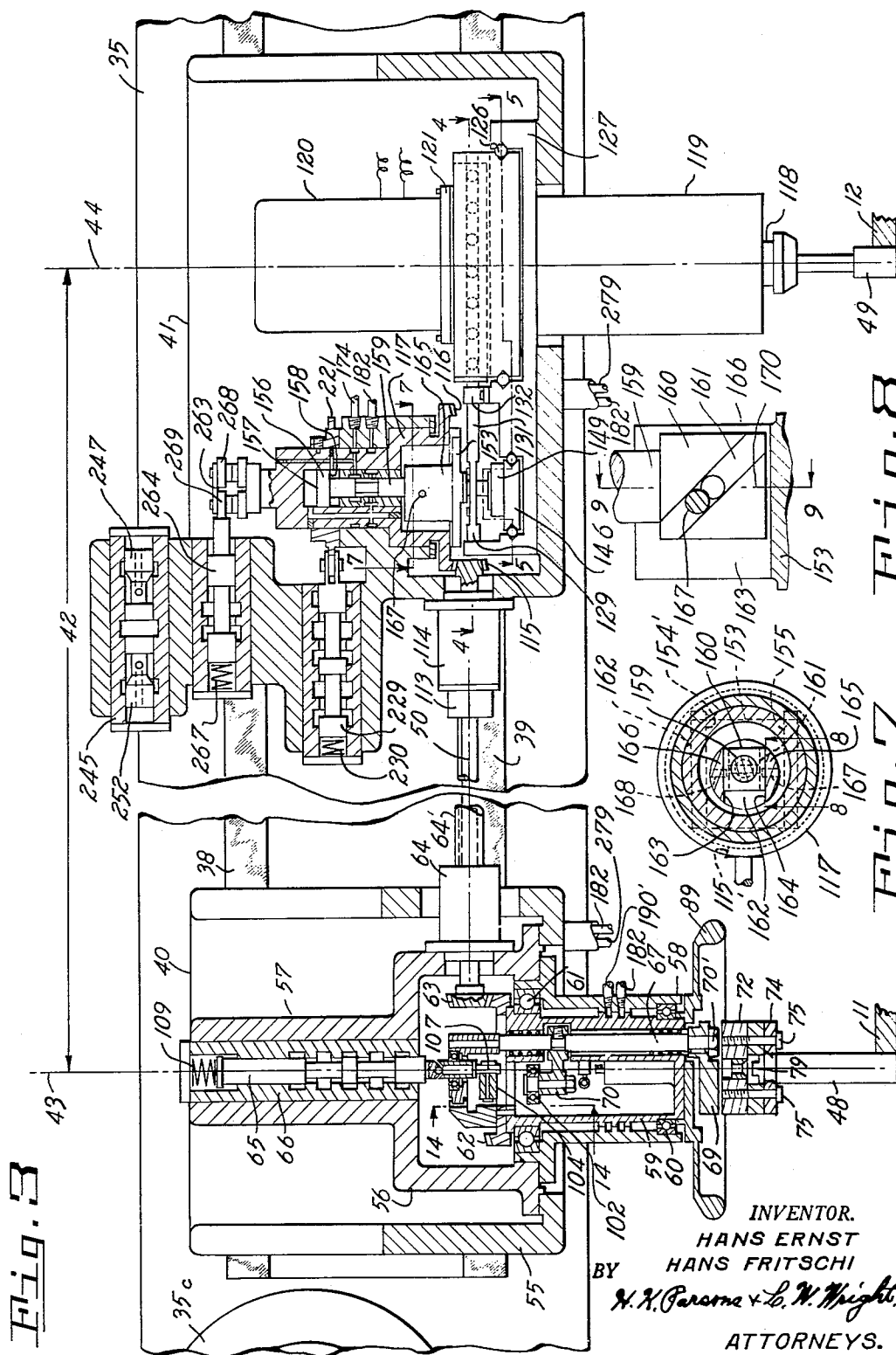
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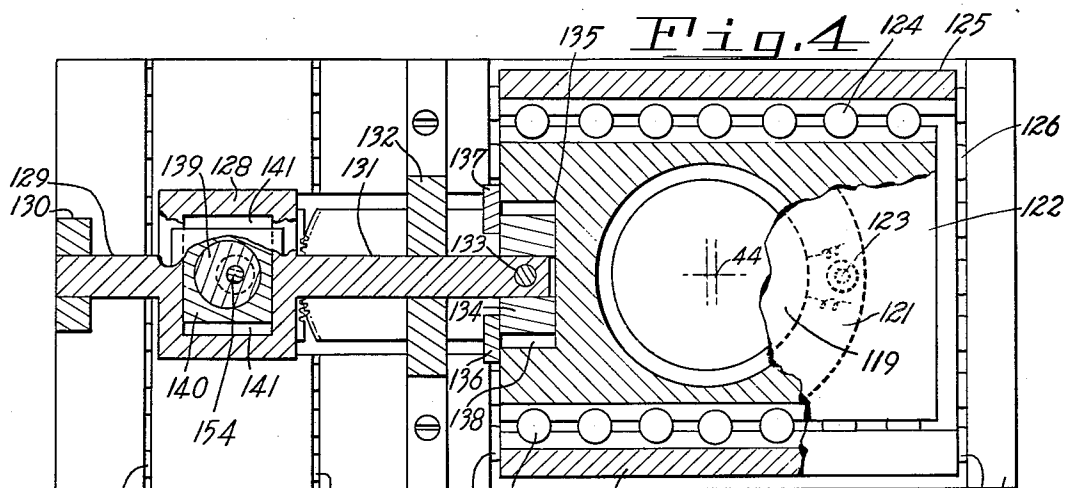
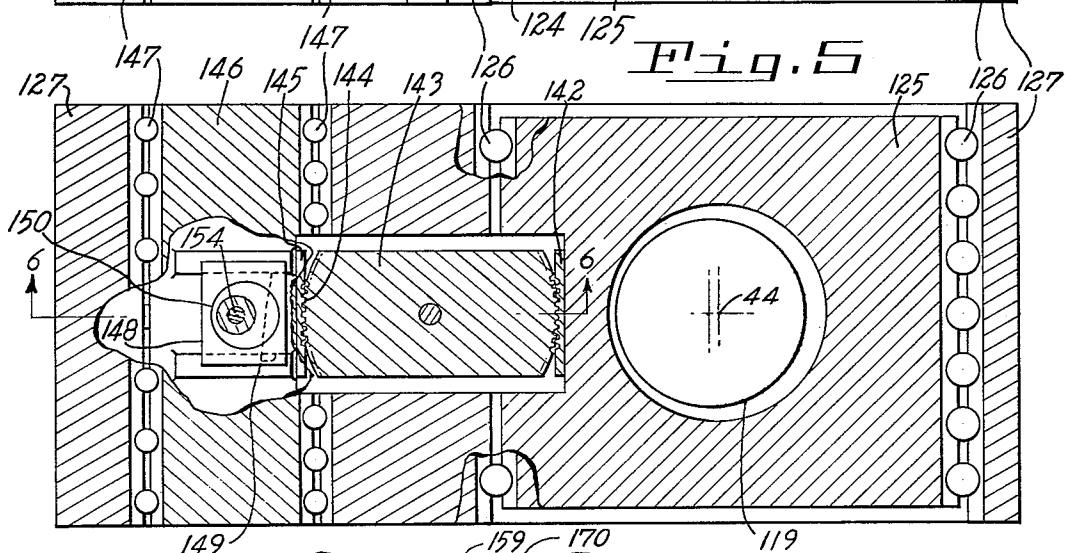
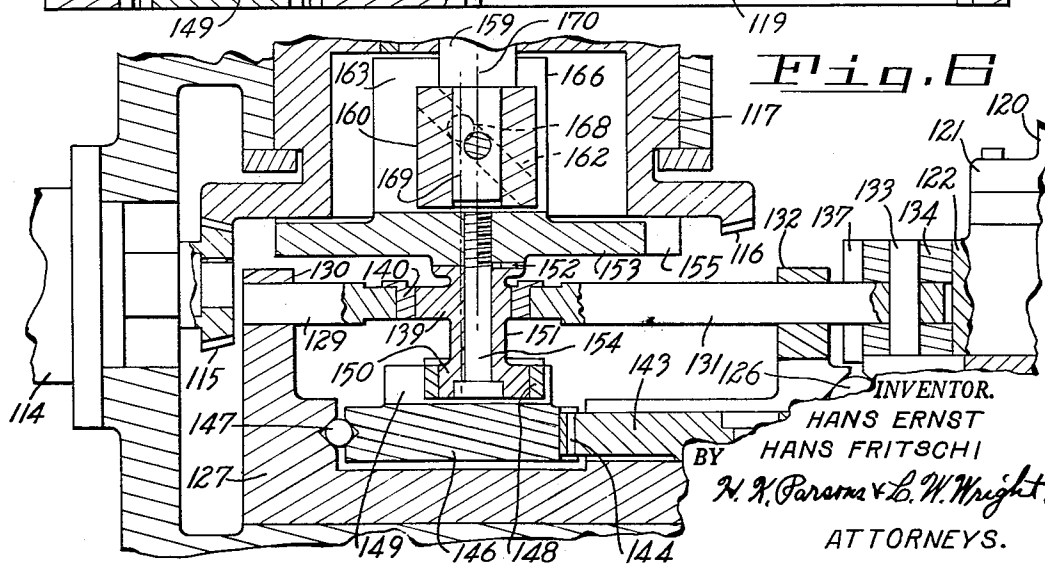
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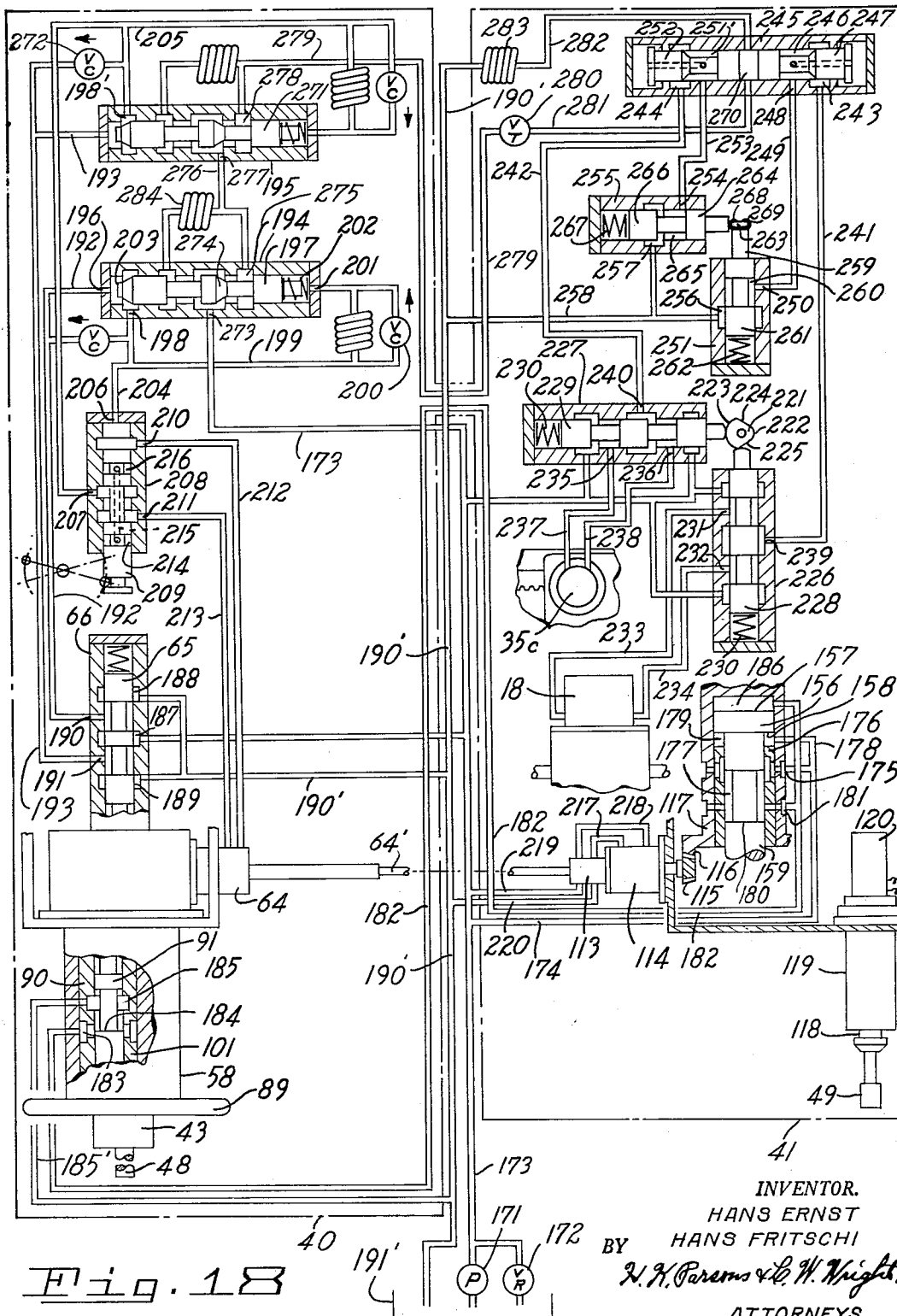
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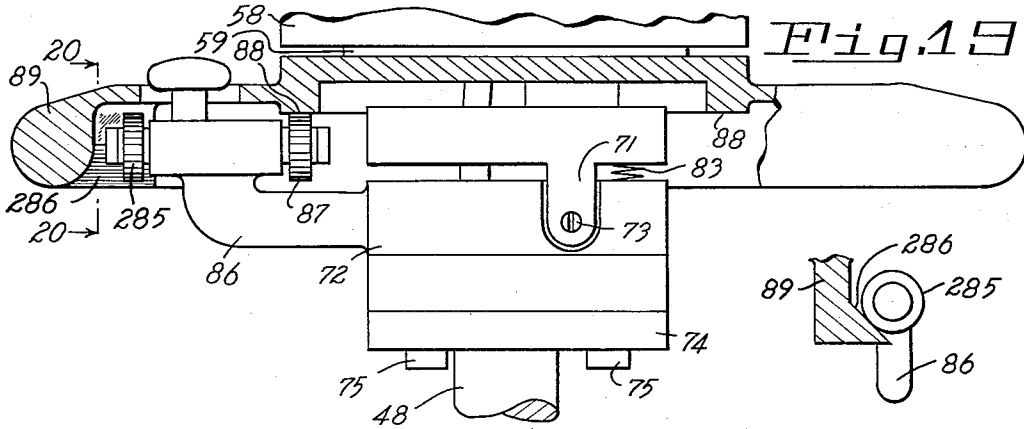
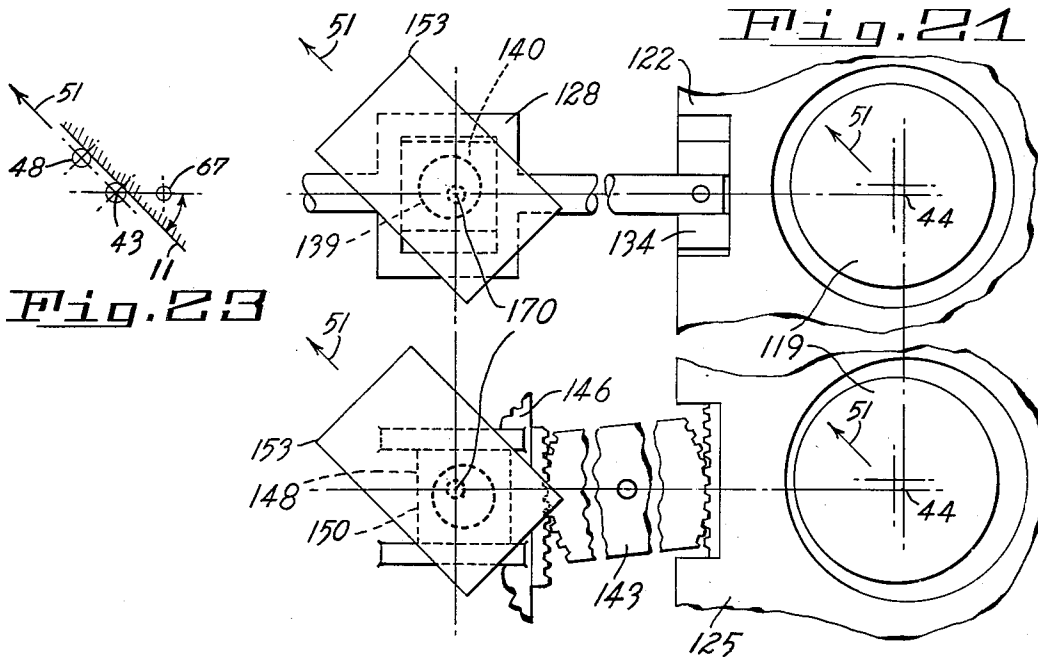
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CUTTER POSITION COMPENSATING MECHANISM FOR PROFILING MACHINES

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6 Sheets-Sheet 6



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1

2,747,469

CUTTER POSITION COMPENSATING MECHANISM FOR PROFILING MACHINES

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Application May 10, 1954, Serial No. 428,752

17 Claims. (Cl. 90—13)

This invention relates to automatic profiling machines and more particularly to a new and improved mechanism for compensating the position of the cutter in accordance with deflective movements of the tracer finger whereby the cutter and tracer finger will more nearly contact corresponding points on the work and pattern throughout a profiling operation.

In modern practice the desire for higher feed rates in profiling operations has led to greater inaccuracies in reproduction because the cutter is in fixed relation with respect to the tracer support, while the end of the deflective tracer finger has a degree of movement relative to the end of the cutter, with the result that the two do not stay exactly in contact with corresponding points on the work and pattern at all times throughout a profiling operation. Furthermore, this degree of relative movement is necessarily increased with increases in the feed rate. A particularly undesirable situation arises in internal profiling operations when the tracer finger enters a square corner and hits a wall at right angles to its direction of feed. The pattern engaging end of the tracer finger is naturally stopped by the wall, while its support continues to move in the feed direction carrying the cutter with it. Before the corrective deflection can be imparted to the tracer to institute a change in the direction of feed, the cutter has over-traveled and removed more material than it should. The faster the feed rate, the greater the inertia to be overcome, resulting in greater overrun and greater damage, as well as inaccuracy.

One of the objects of this invention therefore is to provide an adjustable mounting for the cutter spindle similar to the adjustable mounting of the tracer finger and automatically impart compensating movements to the cutter in conformity with deflective movements of the tracer finger so as to more nearly maintain the finger and cutter in contact with corresponding points on the pattern and work throughout a tracing operation.

Another object of this invention is to provide automatic tracer control of the cutter compensating movements.

A further object of this invention is to provide in conjunction with a rotary tracer head having an eccentric tracer finger, a rotary control head for an eccentric cutter spindle coupled for simultaneous rotation with the tracer head to maintain orientation of both members in the plane of feed regardless of variations in direction of said plane as actuated by the pattern.

Still another object of this invention is to provide new and improved mechanism for a profiling machine in which the cutter as well as the tracer finger are eccentrically positioned with respect to their normal fixed axes on a common support, and to automatically rotate the tracer finger and the cutter about these fixed axes to maintain them oriented in the direction of feed, and to automatically reduce the eccentricity of the cutter whenever the eccentricity of the tracer is automatically reduced by the pattern.

2

Other objects and advantages of the present invention should be readily apparent by reference to the following specification, considered in conjunction with the accompanying drawings forming a part thereof, and it is to be understood that any modifications may be made in the exact structural details there shown and described, within the scope of the appended claims, without departing from or exceeding the spirit of the invention.

Referring to the drawings in which like reference numerals indicate like or similar parts:

Figure 1 is a front elevation of a profiling machine embodying the principles of this invention.

Figure 2 is a plan view of the machine shown in Figure 1.

Figure 3 is a view on the line 3—3 of Figure 2 showing the complete tracer controlled mechanism.

Figure 4 is a section on the line 4—4 of Figure 3.

Figure 5 is a section on the line 5—5 of Figure 3.

Figure 6 is a section on the line 6—6 of Figure 5.

Figure 7 is a section on the line 7—7 of Figure 3.

Figure 8 is a section on the line 8—8 of Figure 7.

Figure 9 is a section on the line 9—9 of Figure 8.

Figure 10 is a section on the line 10—10 of Figure 1.

Figure 11 is a section on the line 11—11 of Figure 1.

Figure 12 is a section on the line 12—12 of Figure 10.

Figure 13 is a section on the line 13—13 of Figure 10.

Figure 14 is a section on the line 14—14 of Figure 3.

Figure 15 is a view of the mechanism shown in Figure 14 as viewed from the right of that figure.

Figure 16 is a fragmentary section on the line 16—16 of Figure 12.

Figure 17 is a fragmentary section on the line 17—17 of Figure 13.

Figure 18 is a diagrammatic view of the hydraulic control circuit.

Figure 19 is a detail view of the hand wheel as viewed on the line 19—19 of Figure 1.

Figure 20 is a detail section on the line 20—20 of Figure 19.

Figure 21 is a diagram of the eccentric shifting of the spindle in one direction by the eccentric shown in Figure 4.

Figure 22 is a diagram of the eccentric shifting of the spindle in a second direction by the eccentric shown in Figure 5.

Figure 23 is a diagram of the resultant shifting effected by both eccentrics.

In Figures 1 and 2 of the drawings there is shown a profiling machine embodying the principles of this invention, and its general construction consists of a bed or support 10 to which is secured a pattern 11 and a work piece 12 by any suitable well-known means. The bed 10 has a longitudinal guideway 13 formed along one side, and a second longitudinal guideway 14 formed along the other side for receiving slidable upright members 15 and 16 respectively. These uprights are suitably tied together by a cross rail 17 which extends crosswise of the bed at a suitable distance above it, and which may be made integral with the uprights. The cross rail has a motor 18 attached thereto for effecting reciprocation of the uprights longitudinally of the bed, and the motion transmitting mechanism for this purpose comprises a pair of bevel gears 20, one of which is driven by the motor 18 and the other of which is attached to a drive shaft 21. The drive shaft is supported on and extends parallel to the cross rail and has beveled gears 22 and 23 suitably secured to opposite ends thereof.

The gear 22 drives, through a bevel gear 23', a vertical shaft 24, journaled in the upright 15 and terminating in a spur gear 25 which meshes with rack teeth 26 formed on the guide 13. Similarly, the gear 23 meshes with a bevel gear 28 secured to the end of vertical shaft 29

journaled in the upright 16 and terminating in a spur gear 30 which meshes with a rack 31 formed on the guide 14. It will now be seen that rotation of the motor 18 will effect a feeding movement of the uprights and cross rail longitudinally of the bed 10 relative to the pattern and work.

Parallel to the cross rail 17 is a slide 32 supported on vertical guideways 33 and 34 formed on the uprights 15 and 16. This slide is vertically adjustable by a handwheel 34a on the end of shaft 34b journaled in slide 32, which carries a pinion 34d meshing with a rack 34c fixed on the upright 15. Mounted on the slide 32 is a saddle 35 mounted on guides 35a and 35b formed on slide 32. It is driven by a motor 35c which has a gear 36 meshing with rack teeth 37 formed on the slide 32 whereby rotation of the motor will feed the saddle 35 relative to the slide 32 and laterally across the bed 10. The saddle 35 has a pair of longitudinally extending guideways 38 and 39 upon which are adjustably mounted a tracer head mechanism 40 and a spindle carrier mechanism 41. Thus a tracer and cutter on these mechanisms are movable longitudinally of the pattern and work by the motor 18, and crosswise by the motor 35c.

For accuracy of reproduction it will be understood that the spacing 42 between the axis 43 of the rotary tracer head of mechanism 40, and the axis 44 of the cutter spindle of mechanism 41 should be equal to the spacing 45 between the axis 46 of the pattern 11, and the axis 47 of the work piece 12; and that the diameter of the tracer finger 48 should preferably be equal to the diameter of the cutter 49. When these relationships exist, it can be said that the tracer and cutter engage corresponding points on the pattern and work respectively.

As shown in Figure 2, the axes 43 and 44 lie in a vertical plane passing through the axis 50 which is parallel to the direction of cross movement of the saddle 35. Therefore, in view of this relationship, the tracer mechanism 40 and the cutter spindle mechanism 41 may be manually adjusted on the guideways 38 and 39 and secured thereto to establish the spacing 42 equal to the spacing 45. Thus, the mechanisms and the saddle 35 are capable of movement in a unit crosswise of the pattern and work, and since all of these are carried by the uprights, they are also movable as a unit longitudinally of the pattern and work.

In order to facilitate the tracer action for high speed tracing, the tracer finger 48, shown in Figure 1, is not supported co-axially with the tracer head axis 43 shown in Figure 2, but is advanced relative thereto in the direction of feed having an eccentric adjustment. Due to the nature and construction of the tracer mechanism utilized herein, an external profiling operation is effected by feeding the tracer relative to the pattern in a clockwise direction around the pattern. In other words, the tracer finger follows around the outside of a pattern in a clockwise direction, whereas in internal profiling operations the tracer follows around the pattern in a counterclockwise direction. Since the pattern 11 requires an external profiling operation, the direction of feed is in the direction of the arrow indicated by the reference numeral 51 in Figure 2, and therefore the tracer finger 48 is adjusted relative to the center or axis 33 of the tracer head in the direction of the arrow 51 a predetermined amount, such as to the position indicated by the reference numeral 52. The amount of this adjustment is represented by the reference numeral 53 and is greatly exaggerated for easy understanding. It will be obvious that when this adjustment has been made, the cutter 49 no longer contacts a point on the work corresponding to the point of contact of the tracer with the pattern.

Therefore, by means of this invention, the cutter 49 is also advanced in the same direction and to the same extent, such as to the position 54. From then on, any change in the direction of feed, or in the distance 53 due to the backward deflection of the tracer finger, is automatically com-

pensated for by a similar change in the position of the cutter relative to its normal fixed axis represented by the axis 44. In order to further understand this invention, it is necessary first to describe the construction of the tracer head. The rotary tracer head shown herein has the same basic principle of tracer action as that shown in our pending application, Serial No. 288,806, now Patent No. 2,730,129, granted January 10, 1956, filed in the United States Patent Office on May 20, 1952.

The tracer head mechanism 40 comprises a box-like frame 55 which is secured to the guideways 38 and 39 as shown in Figure 3. Fixed on the frame 55 is a cylindrical housing 56 having an upward extension 57 forming a tracer valve housing, and a lower cylindrical extension 58 housing a rotary tracer head 59. The rotary head 59 is journaled in anti-friction bearings 60 and 61 in its housing, and at the upper end carries a bevel gear 62 meshing with a bevel gear 63 which is driven by a hydraulic motor 64. Rotation of the hydraulic motor is controlled by a tracer valve mounted in the housing 57. It comprises a valve plunger 65 reciprocable in the valve sleeve 66 in which is formed a plurality of control parts for controlling reversible rotation of the motor 64.

The rotary head 59 has an eccentric shaft 67 journaled therein parallel to the axis of rotation of the head as shown in Figure 10 of the drawings. A crank arm 69, Figures 3 and 11, is secured to the lower end of the shaft 67, and a second crank arm 70 is secured to the upper end of the shaft. The lower crank arm 69 carries means for supporting the tracer finger 48, while the upper crank arm 70 is operatively connected for controlling the shifting of the tracer valve plunger 65. Thus, any lateral movement of the tracer finger 48 will transmit motion to the valve plunger 65 through rotation of the shaft 67 relative to the rotary tracer head.

The lower crank 69 is keyed to the shaft 67 and held thereon by a nut 70' threaded on the end of the shaft, as shown in Figure 3. The crank 69, Figure 11, has a pair of spaced depending ears 71 which are connected to opposite sides of block 72, pivotally supporting it by means of a cross pin 73 extending at right angles to the shaft 67. The tracer finger 48 is provided with an integral flange 74 which is bolted to the block 72 by means of clamping screws 75 which pass through enlarged holes 76 in the flange 74 whereby the axis of the tracer finger may be eccentrically adjusted with respect to the axis of the tracer head. This adjustment may be effected by a pair of set screws 77 and 78 threaded in the block 72 and engaging a square projection 79 formed on the upper end of the tracer finger 48. By means of this adjustment, the axis 80 of the tracer finger may be shifted relative to the axis 43 of the tracer head and normal to the axis of pin 73 a predetermined amount indicated by the reference numeral 82 and in the direction of feed. This is the eccentric adjustment previously referred to and is of a prescribed amount to which the cutter will also be adjusted as explained hereafter. A compression spring 83 is mounted in sockets 84 and 85 formed respectively in the block 72 and the crank arm 69 for effecting a clockwise rotational urge on the block 72 and tracer finger about its pivoted pin 73. This movement is limited by the following means which acts as a positive stop to hold the tracer finger vertical.

The block 72 is provided with a laterally projecting arm 86 which, as shown in Figure 19, has a roller 87 attached thereto, and which engages a locating surface 88 formed on the underside of the hand wheel 89 which is secured to the bottom of the rotary tracer head 59. Thus, it will be seen that the spring 83 holds the parts in a definite rotational position about the pin 73 against the stop surface 88. The parts are so arranged that this locates the tracer finger 48 in a vertical position with its axis parallel to the axis of rotation of the tracer head and the axis of rotation of the cutter.

The purpose of this oscillatable construction of block 72 is to cause operation of a control valve to effect com-

5

compensation in the position of the cutter in the event that the tracer finger should meet a positive abutment that would cause backward deflection of the tracer finger, that is, rotation of the tracer finger 48 opposite to the direction of feed about the pivot pin 73 in a counterclockwise direction as viewed in Figure 11.

This control valve is indicated generally by the reference numeral 90, in Figure 11, and comprises a valve plunger 91 which is pivotally connected at 92 to the end of a lever 93 which serves to support the valve plunger and cause movement thereof. The lever 93 is pivotally connected at 94 to a projecting boss 95 formed on the inside of the rotary tracer head 59. A connecting lever 96 is pivotally connected at 97 to the lever 93 at a point approximately midway between the ends thereof, and the other end is pivotally connected at 98 to a stud 99 projecting from the top of the block 72 and anchored therein by a set screw 100. It will now be seen that when the tracer finger 48 is vertically positioned by the stop means just described that the valve plunger 91 will assume a definite position in its valve sleeve 101 and its ports formed therein and that when the tracer finger is backwardly deflected, the valve will move down. The operation of this valve will be described in connection with the cutter spindle compensating mechanism.

As shown in Figures 14 and 15, the tracer valve operating crank arm 70, which is secured to the upper end of the eccentric shaft 67, as shown in Figure 3, is provided with a roller 102 which engages a roller 103 formed in a depending arm of a bell crank 104 which is pivotally supported on a pin 105 mounted in a boss 106 formed on the tracer head 59. The bell crank 104 has a second roller 107 secured to its other arm 108 and positioned to engage the lower end of the tracer valve plunger 65. It will now be seen that lateral movement of the crank arm 70, as viewed in Figure 14, will cause rotation of the bell crank 104 and cause axial movement of the tracer valve plunger 65 which is held in engagement with the roller 107 by means of a spring 109 shown in Figure 3.

Another spring 110 is connected at one end to a dependent arm 111 of the bell crank 104 and at the other end to a pin 112 fixed in the tracer head 59. The object of this spring is to cause rotation of the crank 70 and thereby of the shaft 67 and lower crank 69 in a clockwise direction as viewed in plan to continually urge the tracer finger 48 into engagement with the pattern and maintain engagement therewith during the tracing operation.

The operation of the tracer mechanism during a tracing operation can be more clearly understood from the diagram in Figure 23, where the axis 43 of the tracer head forms a reference point for explanation of the relationship of the parts. With respect to the surface of the pattern 11 to be followed, it will be noted that the tracer finger 48 is on one side of the pattern line, while the axis of the shaft 67 is on the other side of the pattern line. Thus, a line connecting axis 43 with the axis of shaft 67 is at an angle to the direction of feed 51, preferably about 45 degrees. With the parts in this relation, the tracer valve is held in a central or neutral position, so that any lateral movement of the tracer finger 48 to the right or left of the axis of feed will open the tracer valve, either above or below its neutral position, and cause rotation of the hydraulic motor 64 in one direction or the other and thereby corresponding rotation of the tracer head.

It will be noted, however, that the rotation of the tracer head is about the axis 43, whereby the tracer finger and the shaft 67 will be moved clockwise or counterclockwise about said axis as a center and reposition the tracer finger so that it always points in the direction of feed from the axis 43 and parallel to a tangent at the point of contact with the pattern.

This tracer action is independent of the other tracer action, wherein the tracer is deflected backward about pivot 73 by a pattern wall, such as one at right angles to

6

the direction of feed. This causes operation of valve plunger 91.

The tracer thus has two actions, one of which causes rotation of the tracer head to change the direction of feed in accordance with changes in the pattern, and the other, operation of the compensating control valve plunger 91. Both of these actions are transmitted to the cutter spindle mechanism to effect certain adjustments in the position of the cutter relative to its main support.

The hydraulic motor 64, besides causing a rotation of the rotary tracer head, also causes rotation of the spindle head, and is connected by a telescoping shaft connection 64', as shown in Figure 1 to a rotary servo-valve 113, which is hydraulically connected to cause rotation of a hydraulic motor 114 coupled in feed-back relation to the servo-valve 113. The motor 114 drives through bevel gears 115 and 116, Figure 3, a second rotary head 117 which is journaled in a fixed part of the framework 41. Since the tracer finger is laterally adjustable in a horizontal plane with respect to the axis of the tracer head, the same kind of adjustment must be imparted to the cutter in order to maintain the cutter in positional correspondence with the tracer. The rotary head 117 operates to maintain this adjustment.

The cutter 49 is attached to the end of a cutter spindle 118 which is journaled in a conventional manner in the cutter spindle quill or housing 119, and attached to the upper part of this housing is an electric motor 120 for driving said spindle. The parts 119 and 120 constitute a unit provided with a flange 121 by which the unit is secured to an anti-frictionally supported slide 122, shown in Figure 4, by suitable screws or bolts 123.

As shown in Figure 4, the slide 122 is supported by anti-friction means 124 in a second slide 125, which is supported by anti-friction means 126 in a fixed part 127 of the frame 41 as shown in Figure 5. It will thus be apparent that movement of slide 122 will effect one linear direction of movement of the cutter spindle, and movement of the slide 125 will effect a second direction of movement normal to the first direction of movement. It will also be apparent that by simultaneous movement of both slides, at the same rate or at different rates, will effect angular movement of the cutter spindle in any direction in a horizontal plane with respect to the fixed axis 44, and thereby renders the cutter adjustable in the same manner as the tracer.

The slide 122 is operatively connected to a yoke member 128, which has oppositely extending supporting arms 129 journaled in bearing block 130, and 131 journaled in bearing block 132. The arm 131 is connected by a pin 133 to a block 134 which is slidable in a recess 135 formed in the slide 122 and held therein by guide members 136 and 137. It will be noted that there is clearance space 138 on opposite sides of the block 134 which permits the slide 122 to be moved laterally by the slide 125 which is necessary because the block 134 is held against movement in that direction by the bearing blocks 130 and 132. The yoke member 128 is moved axially by an eccentric cam 139 journaled in a sliding block 140 mounted in the yoke 128. It will be noted that there is a clearance 141 at opposite ends of the member 140 whereby rotation of the eccentric will only cause axial movement of the arms 129 and 131, movement in the other direction amounting to merely lost motion.

The slide 125 is provided with a rack 142, Figure 5, which meshes with a pivoted gear member 143 that has gear teeth 144 meshing with a rack bar 145 on a slide 146 supported by anti-frictional means 147 in the frame 127. A cam block 148 is suitably guided at 149, whereby the block 148 has lost motion movement, as shown in Figure 5, in a direction from left to right, but movement of the block 148 at right angles to this direction will cause movement of the rack bar 145 and thereby, through the intermediate gear member 143, movement of the slide 125 toward the top or bottom of the drawing.

The block 148 has an eccentric cam 150 journaled therein whereby rotation of the cam will produce a desired movement in one direction, and a lost motion movement in a direction at right angles thereto. The cams 139 and 150 are formed on a common member, but in 180 degree phase relation as shown in Figure 6, although they could be made separately. This member, indicated by the reference numeral 151, is keyed at 152 to a supporting member 153 and secured thereto by a bolt 154. The member 153 is confined between guideways 154' and 155 formed on the rotary head 117 whereby rotation of the head 117 will, through the member 153, cause rotation of the cams 139 and 150. The member 153 is capable of sliding movement relative to the member 117, and it is to be noted that when the member 153 is in such position that the axis through the center of the cams 139 and 150 is co-axially aligned with the axis of rotation of the head 117, no lateral displacement of the axis of the cutter spindle will be effected.

The control member 153 is shifted by a piston 156 which, as shown in Figure 3, is a differential piston having a large face 157 and a smaller face 158 so related that when a given pump pressure is applied to the face 158 and one-half of that pressure is applied to the face 157, the piston is in balance. The piston 156 has a piston rod 159 depending therefrom, and the lower end of this rod has a square block 160 pinned thereto, Figure 9, in the opposite sides of which are formed camming grooves 161 and 162 which extend at an angle of 45 degrees to the direction of axial movement of the piston rod as shown in Figure 8. The member 153 has a cross slot 162' cut in the reduced upper portion thereof forming guide faces 163 and 164 which bear against the opposing faces of the square block 160.

This cross slot forms bifurcations 165 and 166, as shown in Figures 7 and 9, and camming pins 167 and 168 are driven into these bifurcations and extend into the cam groove 161 and 162. Thus, any axial movement of the piston rod 159 will cause the control member 153 to be moved along its guideway and thereby shift the axis 169 of the cams 139 and 150 relative to the axis 170 of the rotary head 117. The movement of the piston 156 is controlled by the control valve 90 which, as previously described, is located in the tracer head as shown in Figure 11. The operation of this valve will now be explained.

Referring to the hydraulic diagram in Figure 18, a source of constant pressure, such as the pump 171 having a relief valve 172, is connected through conduit 173 and branch conduit 174 to pressure port 175 in valve sleeve 176. This port is in constant communication with an annular groove 177 formed in the piston rod 159 whereby pump pressure always exists in this groove. The conduit 174 has a branch connection 178 which communicates with the lower cylinder space 179 whereby the pump pressure always exerts an upward force on the face 158 of piston 156.

The piston rod 159 has a valve shoulder 180 which moves relative to a port 181 to variably restrict the flow of fluid from the annular groove 177 to channel 182. The resistance to flow at the port 181 constitutes a resistance into the channel 182. The channel 182 terminates in a port 183 of valve 90, the plunger of which has a shoulder 184 which is movable relative to the port 183 to variably restrict the flow of fluid through that port into the annular groove 185 formed in the valve plunger 91, which groove is connected to reservoir by line 185'. The resistance at port 183 constitutes a resistance "out" of the channel 182, and according to the laws of hydraulics when the resistance "in," such as at port 181, is equal to the resistance "out," such as the resistance at the port 183, the pressure in the intermediate space, which in this case is the channel 182, will be equal to one-half of the incoming pressure. Since the incoming pressure is the pressure of the pump which exists in the

annular groove 177, the pressure in the channel 182 will be one-half of the pump pressure.

The channel 182 is connected to the upper cylindrical space 186 and acts on the large face 157 of the piston 156, while the full pump pressure acts on the small face 158 of the piston and thereby holds the piston in balance. With the piston held in balance, any movement caused by the tracer of the shoulder 184 in valve 90 relative to its port 183 will change the resistance at that port and either increase or decrease the resistance dependent on the direction of movement. This produces a corresponding pressure change in the channel 182, which is greater or less than the constant pump pressure acting on the other side of the piston 156 whereby the piston 156 will be moved.

Therefore, if the tracer finger 48 should hit a positive abutment during its traversing movement and should be deflected backward to cause movement of the valve plunger 91, it will cause a corresponding change in pressure on the piston 156 and cause the same to move in a direction to shift the cutter relative to its supporting frame. This will always be in the relationship that the cutter will be moved backward in a direction opposite to the direction of feed of its support, and the movement of one will in effect cancel the movement of the other in space, with the result that the cutter 49 will remain stationary and thereby no overrun to spoil the work.

In the description of Figure 11, it was pointed out that the tracer finger has an eccentric adjustment, represented by the reference numeral 82. Since it is desired that the cutter engage a corresponding point on the work, it is necessary that the cutter have the same eccentric adjustment relative to its normal position represented by the axis 44. Therefore, the valve 90 is so set in the construction of the device that the neutral position or balanced condition of piston 156 is such that the cutter has this initial eccentric relation with respect to the axis 44.

In the operation of the machine the tracer is held in engagement with the pattern by a spring and when the tracer arm is at an angle to the pattern surface, such as at an angle of 45 degrees which has been found very satisfactory, the tracer valve is in a neutral or stop position.

Referring again to the hydraulic diagram, Figure 18, the tracer valve has the source of pressure, pump 171, connected to its pressure port 187, and there are two exhaust ports 188 and 189 which are connected by channel 190' to reservoir 191' from which the pump withdraws its fluid. There are two motor ports 190 and 191 in the valve, and these are connected by channels 192 and 193 to the motor 64 through automatic throttle valves 194 and 195. These valves operate in the same manner; therefore, description of one should suffice for both.

Valve 194, for instance, has the channel 192 connected to an end port 196 whereby when fluid pressure enters the valve housing it will shift the valve plunger 197 to the right, as viewed in Figure 18, and uncover port 198. The fluid pressure will then continue through line 199 and check valve 200 to port 201 located in the opposite end of valve 194 to thereby urge the valve plunger to the left. This action will be aided by the spring 202 which will cause closure of the port 198. As port 198 closes it creates a resistance to flow in the line 199 and thereby causes a drop in pressure on the right hand end of the plunger. It will be seen from this action that the pressure in the opposite ends of the valve will automatically balance and thereby stabilize the position of the plunger.

If the channel 192 is connected to exhaust, the pressure of the spring will be greater than the pressure in the left end and the port 198 would be closed. However, it is better that the plunger be in such position that the port is just cracked open. To this end the plunger has a reduced end 203 which will abut the end of the valve housing to limit the movement of the plunger to this particular

position. This maintains the lines full of oil and ready for operation.

The oil passing through the ports 198 and 198' will pass through lines 204 and 205 respectively to ports 206 and 207 of a manual selector valve 208. This valve has a plunger 209 which is normally in a downward position, as shown, by which the port 206 is connected to port 210, and port 207 is connected to port 211. These ports are connected by channels 212 and 213 to the hydraulic motor 64. If the channels were all full of oil it will now be seen that any movement of the tracer valve plunger 65 to either side of its central position will unbalance the pressure in lines 212 and 213 and cause rotation of the hydraulic motor 64 in one or the other direction and thereby rotation of the tracer head.

Should it be desirable to rotate the tracer head manually as by means of the hand wheel 89, the valve plunger 209 is moved upward, thereby short-circuiting port 211 with port 210 by means of annular groove 214, interdrilled passage 215 in valve plunger 209 and annular groove 216. It will be understood that the grooves 214 and 216 will be opposite ports 211 and 210 at this time.

The hydraulic motor 64 is operatively connected to the rotary servo-valve 113 by means of the telescoping shaft 64'. The rotary servo-valve is connected by hydraulic channels 217 and 218 to the rotary hydraulic motor 114. This combination of rotary servo-valve and rotary motor is known in the art and may be the same as that shown in United States Letters Patent 2,349,641. Pressure to the servo-valve is derived from the pump 171, through line 173 and branch conduit 219, while the other side of the servo-valve is connected by branch line 220 to the common return line 190'. It will thus be seen that rotation of the hydraulic motor 64 will automatically cause a similar amount of rotation of the hydraulic motor 114.

The rotary spindle head 117 not only controls the positioning of the cutter spindle through the mechanism described supra, but also directly controls the rate and direction of relative movement between the cutter and the work effected by motors 18 and 35c. Thus, these three functions are controlled directly by the rotary position of the single control member 117. To this end, the rotary head 117 has a cam 221 fixed thereto, which has a small radius 222, a large radius 223, and crossover points 224 and 225. As shown in Figure 18, reversing valves 226 and 227 have valve plungers 228 and 229 which are held in engagement with the cam 221 by springs 230. The valves are arranged 90 degrees apart, and the valve 226 controls reversible operation of motor 18, while valve 227 controls reversible operation of hydraulic motor 35c.

When either of the valve plungers 228 or 229 are in engagement with the crossover points on the cam 221, it is held in a central or neutral position; and when in engagement with the small radius 222 it is positioned to one side of its neutral position; and when in engagement with the large radius 223 it is positioned to the other side of its neutral position. The valve 226 has motor ports 231 and 232 which are connected by channels 233 and 234 to the hydraulic motor 18, and the valve 227 has motor ports 235 and 236 which are connected by channels 237 and 238 to motor 35c. The pressure ports of these valves are connected to the pump supply line 173, and the exhaust ports 239 and 240 respectively are connected by channels 241 and 242 to ports 243 and 244 of a balancing valve, indicated generally by the reference numeral 245. The port 243 is connectible by annular groove 246 in valve plunger 247 to port 248, and channel 249 to port 250 of a rate valve indicated generally by the reference numeral 251.

Similarly, the port 244 is connected by annular groove 251', valve plunger 252, and channel 253 to port 254 of rate control valve 255. The valves 251 and 255 have variable throttle ports 256 and 257 which are connected to a common branch line 258 leading to the common return line 190'. The rate valve 251 has a valve plunger

259 on which is formed an annular groove 260 and a spool 261 which controls the flow from port 250 to port 256. A spring 262 holds this plunger in engagement with a rate control mechanism 263 which, as shown in Figure 3, is attached to the rotary member 117.

Similarly, the valve 255 has a plunger 264 on which is formed an annular groove 265 and a spool 266 which controls the flow from port 254 to the port 257. This plunger is held by a spring 267 in engagement with the rate control mechanism 263. These valves are arranged 90 degrees apart, and the rate control mechanism comprises two rollers 268 and 269 arranged side by side whereby, as the member 117 rotates, one of the plungers moves inward while the other moves outward. When the valve plunger 259 is in engagement with both rollers, as shown in Figure 18, the port 256 is closed, while the plunger 264, being in engagement with only one roller, the port 257 is open.

It will now be seen that the rate and direction of rotation of the hydraulic motor 18 is controlled by the valves 226 and 251 and that they operate upon the return flow from the motors. In other words, the valve 226 determines the direction of rotation of the motor 18 like any other reversing valve, and the flow from this valve passes through line 241 and valve 245 in line 249 to the throttle valve 251 whereby the variable throttling of the port 256 controls the rate. Likewise, the valve 227 determines the direction of rotation of the motor 35c and the valve 255 determines the rate of operation of the motor through variable throttling of port 257.

The resultant feed rate, which is the combined effect of motors 18 and 35c, is controlled by the position of the plungers in valve 245 which is determined by the hydraulic pressure in the chamber 270, located between the ends of the plungers 247 and 252. Pressure is supplied to this chamber by pump 171. However, this pressure is a function of the rate of flow to the tracer head hydraulic motor 64, and the valves 194 and 195 are the means for deriving this function. As previously described, the valve 194 has its end portion serially connected in line 212 going to one side of the hydraulic motor 64, and the valve 195 has a portion serially connected with line 213 going to the other side of the hydraulic motor. Thus, regardless of which line is delivering fluid to the hydraulic motor, there is a valve responsive to that flow.

Both of these valves have another portion which is serially connected between the pump and the hydraulic chamber 270, and their function is to reduce the flow to the chamber 270 when the flow to the hydraulic motor 64 is increased. Since there cannot be flow to the motor 64 through both lines 212 and 213 at the same time, one of the valve ports 198, 198' will be closed and the other open, which means one valve plunger will be in its left hand position and the other plunger shifted to the right. Assume, therefore, that the plunger 197 is shifted to the right, as shown, due to flow in line 192 to the motor 64, the other plunger 271 is to the left, closing port 198', whereby the return flow from the motor passes through the check valve 272 to line 193 which at this time would be connected to reservoir by the tracer valve.

The pump 171 is connected to port 273 of valve 194, and the plunger 197 has a tapered spool 274 in position to restrict the flow to port 275, thus causing a drop in pressure which is reflected in chamber 270, causing plungers 247 and 252 to move toward one another, and thereby restrict flow through the valve 245 and thus slow the feed rate.

The port 275 is connected by channel 276 to port 277 of valve 195, and plunger 271 of this valve has a tapered spool, controlling port 278, but since the plunger is to the left, there is free flow through port 278 and line 279 to throttle valve 280, which is adjustable to set the original pressure in chamber 270 and thereby determine the normal feed rate. Fluid passes from throttle valve 280, through

line 281, chamber 270, line 282, to resistance 283 which is connected to the reservoir line 190'.

Since the throttle valve 280 constitutes a resistance "in" to chamber 270, and the resistance 283 constitutes a resistance "out" of chamber 270, it becomes possible to vary the pressure in chamber 270, either by varying the setting of the throttle valve, or causing a prior drop in pressure to the fluid supplied to the throttle valve as by means of valves 194 and 195.

It is to be noted that if the spool 274 closes port 275, the fluid will be caused to flow through the resistance 284, thereby insuring that there is always a flow through the chamber 270 so as to maintain some degree of pressure therein.

When valve 194 is to the left and the valve 195 opens to permit flow to the hydraulic motor 64, it will be obvious that the valve 195 functions to restrict the flow to chamber 270 and valve 194 permits free flow therethrough. It will now be seen that each time the tracer valve opens that there is an automatic reduction in feed rate, and that there is an automatic repositioning of the cutter spindle with respect to its normal axis 44 so that it is oriented the same as the tracer, and in the direction of feed.

It will now be evident that there is a tracer mechanism of a type in which the tracer finger is adjustably set ahead in the direction of feed with respect to the axis of rotation of the tracer head as a reference point, but which is actually pivotally connected to the tracer head on the opposite side of its axis with respect to the tracer finger. This pivotal connection is also normally on the opposite side of the profile line of the pattern with respect to the tracer finger. The object of rotating the tracer head is to maintain the imaginary radial line from the axis of the tracer head through the axis of the tracer finger always parallel to the pattern, or more precisely, parallel to a tangent of the pattern at the point of contact of the pattern with the tracer. Although this is a very efficient form of tracer from a tracing action standpoint, it will be noted that the tracer finger would not contact a point on the pattern corresponding to the same point on the work, if the cutter spindle axis was in its normal position, that is, spaced from the axis of the tracer head equal to the spacing of corresponding points on the pattern and work. Therefore, by means of this invention the cutter axis is positioned ahead of its normal position in the same manner as the tracer finger by the means shown in Figures 21 and 22, so that its actual position is oriented with respect to its normal position as a reference point. Then the imaginary radius connecting these two axes will point in the direction of feed. Once this is established, then the spindle head is rotated simultaneously with the tracer head to keep the radii always parallel.

It will now be evident that there is a tracer mechanism of a type in which the tracer finger is adjustably set ahead in the direction of feed with respect to the axis of rotation of the tracer head. This setting ahead is necessary to obtain efficient tracer action, because unlike universally mounted tracers, this tracer is connected to a rotatable shaft and acts like a crank to rotate the shaft and operate the tracer valve. Therefore, the tracer moves in an arc normal to the pattern surface in its normal tracing action which it will be noted is crosswise of the direction of feed. Therefore, since the tracer is set ahead, by means of this invention, the cutter is set ahead to compensate its position as shown in Figures 21 and 22.

Attention is invited to the fact, which by now should be obvious, that in order to change the direction of feed, a lateral movement must be imparted to the tracer in order to actuate the tracer valve to effect the direction change. It will be noted, however, that when the tracer meets a wall, such as in a right angle corner, the tracer is simply moved backward about the pivot pin 73. This does not cause lateral movement of the tracer finger, and the feed direction would not change, and thus the

tracer would stall in the corner. To overcome this trouble, as shown in Figures 19 and 20, the arm 86 is provided with another roller 285 which as shown in Figure 20 rests on an inclined surface 286, formed on the underside of the handwheel 89. Thus, whenever the tracer finger 48 is moved backward, that is to the right as viewed in Figure 19 about pin 73, the inclined surface 286 acting on roller 285 will cause arm 86 to swing and cause rotation of the block 72 and shaft 67, as shown in Figure 11, to actuate the tracer valve and change the feed direction.

There has thus been provided a new and improved construction whereby a cutter and a deflectible tracer finger may be maintained more nearly in contact with corresponding points on the pattern and work throughout a profiling operation regardless of variations in the deflection or orientation of the tracer finger whereby faster and more accurate profiling operations may be obtained.

What is claimed is:

1. In a profiling machine having a rotary tracer head and a cutter spindle supported on the machine with their axes in parallel relation and normally spaced in accordance with the spacing of a pattern and work piece to be engaged thereby, the combination of a tracer finger carrier by the tracer head in co-axial relation therewith, means to laterally adjust the tracer finger to offset its axis relative to the axis of the tracer head, and means supporting the cutter spindle for lateral movement relative to the axis of the tracer head whereby the cutter spindle may be laterally offset with respect to its said normal position an amount equal to said offset of the tracer finger.

2. In a profiling machine having a rotary tracer head mounted thereon, the combination of a cutter spindle mounted on the machine with its axis parallel to the axis of the tracer head and normally spaced therefrom equal to the spacing of a pattern and work piece carried by the machine, a tracer finger supported by the tracer head coaxial with the axis of said head, means to adjust the tracer finger eccentrically to the axis of the tracer head a predetermined amount, and means to adjust the cutter spindle eccentrically to its said normal position the same predetermined amount.

3. In a profiling machine having a rotary tracer head mounted thereon, the combination of a cutter spindle housing mounted on the machine with its spindle axis normally spaced from the axis of the tracer head a distance equal to the spacing of the pattern and work on the machine, a tracer finger supported by the tracer head in co-axial relation therewith, means to adjust the tracer finger radially of the axis of the tracer head a predetermined amount, and means to adjust the cutter spindle housing radially of the said normal position of the spindle the same predetermined amount.

4. In a profiling machine having a rotary tracer head mounted thereon, the combination of a cutter spindle housing mounted on the machine with its spindle axis in a normal position spaced from the axis of said tracer head equal to the spacing of a pattern and work piece to be engaged, a tracer finger mounted on the tracer head with its axis radially adjusted with respect to the axis of the tracer head a predetermined amount, means to adjust the cutter spindle housing radially of said normal position of the spindle axis the same predetermined amount, and means to effect rotation of the tracer head and simultaneous rotation of the cutter spindle housing about the normal position of the spindle axis.

5. In a profiling machine having a rotary tracer head mounted thereon, the combination of a tracer finger mounted on said head with its longitudinal axis eccentric to the axis of rotation of the tracer head a predetermined amount in a radial direction, a cutter spindle housing containing a cutter spindle mounted on the machine with the axis of the cutter spindle spaced from the axis of the

tracer head in a normal position equal to the spacing of the pattern and work carried by the machine, means to radially adjust said spindle with respect to its normal position in a direction parallel to the radial plane of adjustment of the tracer finger and the same predetermined amount.

6. In a profiling machine having a rotary tracer head mounted thereon and a tracer finger supported by the head with its longitudinal axis eccentrically located with respect to the axis of rotation of said head, the combination of means for supporting the tracer finger for oscillation about an axis normal to its longitudinal axis and normal to the direction of feed, a cutter spindle supported on the machine with its longitudinal axis in a normal position spaced from the axis of the tracer head equal to the spacing of the pattern and work carried by the machine, means to eccentrically adjust said spindle radially of its normal position equal to the eccentric adjustment of the tracer, and means to bodily shift the cutter spindle in the plane of feed approximately equal to the oscillatory movement of the end of the tracer finger.

7. In a profiling machine having a rotary tracer head and a cutter spindle mounted on the machine in normal positions spaced apart equal to the spacing of a pattern and work piece mounted on the machine, the combination of a tracer finger supported on the tracer head, means to effect a relative feeding movement of the tracer finger and cutter relative to the pattern and work respectively, means to eccentrically adjust the tracer finger with respect to the axis of the tracer head and the cutter spindle with respect to its said normal position in the direction of the feeding movement, power operable means for rotating the tracer head in response to deflection of the tracer laterally of the direction of feed, and motion transmitting connections simultaneously operated by said power operable means to adjust the cutter spindle laterally of the direction of feed to maintain the tracer and cutter in contact with corresponding points on the pattern and work.

8. In a profiling machine having a rotary tracer head and power operable means for rotating said head, the combination of a cutter spindle, a housing supporting the cutter spindle, means supporting the housing in the machine for bodily rotary movement about an axis eccentric to the axis of the spindle, and means connecting said power operable means to effect the rotary movement of said housing.

9. In a profiling machine having a rotary tracer head and power operable means for rotating said head, the combination of a cutter spindle, a pair of superimposed slides supported in the machine for movement at right angles, a housing for the cutter spindle supported on one of said slides, and motion transmitting means connecting said power operable means to said slides in a manner to effect bodily, rotary movement of said housing about an axis eccentric to the axis of said spindle.

10. In a profiling machine having a first rotary head, a tracer finger supported on said head eccentric to the axis of rotation thereof for movement in a first circle, a cutter spindle supported in the machine for movement in a circle having a radius equal to the radius of said first circle, and a common power means for effecting circular movement of the tracer finger and the cutter spindle.

11. In a profiling machine having a rotary tracer head and power operable means for rotating said head, the combination with a cutter spindle of a second rotary head coupled to said power means for simultaneous rotation with the tracer head, said second head having a slide movable diametrically of its axis of rotation, an eccentric mechanism carried by said slide and movable therewith to vary the degree of eccentricity of said mechanism, a cutter spindle supported for universal movement in a plane at right angles to its axis including support mechanism, and means coupling said support mechanism to

said eccentric mechanism for controlling the position thereof.

12. In a profiling machine having a rotary tracer head, power operable means for rotating said head, and a tracer finger supported by the head eccentric to the axis of rotation thereof, the combination of a second rotary head carrying a slide shiftable diametrically to its axis of rotation, an eccentric means carried by said slide for shifting thereby to various eccentric positions relative to the axis of rotation of said head, means supporting the tracer finger for oscillatory movement about an axis normal to the axis of rotation of the tracer head, and automatic servo-control power means responsive to oscillation of the tracer to effect shifting of said slide.

13. In a profiling machine having a tool and a work support, power operable means for effecting a relative feeding movement between said supports and a rotatable tracer head mounted on the tool support and having a prescribed radial plane, the rotatable position of which determines the direction of said feeding movement, the combination of a tracer finger lying in said plane parallel to the axis of said head, means eccentrically of the axis of said head for pivotally supporting said tracer finger for oscillation in said radial plane, a cutter spindle lying parallel to said tracer finger and normally spaced therefrom a distance equal to the spacing of the pattern and work in the machine, means supporting the said cutter spindle for universal movement laterally of its axis in a plane normal to its axis, and power operable means responsive to oscillatory movement of the tracer finger in said radial plane for laterally moving the cutter spindle parallel to the plane of feed in amounts substantially equal to the movement of the contacting end of the tracer.

14. In a profiling machine having a tool and a work support, power operable means for effecting a relative feeding movement between said supports and a rotatable tracer head mounted on the tool support and having a prescribed radial plane, the rotatable position of which determines the direction of said feeding movement, the combination of a tracer finger lying in said plane parallel to the axis of said head, means eccentrically of the axis of said head for pivotally supporting said tracer finger for oscillation in said radial plane, a cutter spindle lying parallel to said tracer finger and normally spaced therefrom a distance equal to the spacing of the pattern and work in the machine, means supporting the said cutter spindle for universal movement laterally of its axis in a plane normal to its axis, and power operable means responsive to oscillatory movement of the tracer finger in said radial plane for laterally moving the cutter spindle parallel to the plane of feed in amounts substantially equal to the movement of the contacting end of the tracer, said last-named power operable means comprising a servo-motor mounted on the tool support, and a servo-valve mounted in the tracer head and operatively connected to said tracer finger.

15. In a profiling machine having tool and work supports, power operable means for effecting a relative feeding movement between said supports and a rotatable tracer head mounted on the tool support for controlling the direction of said feeding movement effected by said power operable means, the direction of said feed lying in a prescribed radial plane of said tracer head, the combination of a tracer finger lying in said radial plane with its longitudinal axis parallel to that of the axis of the tracer head, means pivotally supporting the tracer finger for oscillation in said plane, said pivotal supporting means lying eccentric to the axis of the tracer head, a cutter spindle, a pair of superimposed slides supporting said spindle on the tool support, said slides being movable normal to each other, a pintle pin carrying cams connected to the respective slides, means supporting said pintle pin for rectilinear or circular movement, power means responsive to oscillation of said tracer finger in

15

said radial plane for effecting said rectilinear movement, and additional power operable means responsive to lateral movement of said tracer finger to effect rotation of said tracer head and circular movement of said pin.

16. In a profiling machine having a tool and a work support, power operable means for effecting a relative feeding movement between said supports and a rotatable tracer head mounted on the tool support and having a prescribed radial plane, the rotatable position of which determines the direction of said feeding movement, the combination of a tracer finger lying in said plane parallel to the axis of said head, means eccentrically of the axis of said head for pivotally supporting said tracer finger for oscillation in said radial plane, a cutter spindle lying parallel to said tracer finger and normally spaced therefrom a distance equal to the spacing of the pattern and work in the machine, means supporting the said cutter spindle for universal movement laterally of its axis in a plane normal to its axis, and power operable means responsive to oscillatory movement of the tracer finger in said radial plane for laterally moving the cutter spindle parallel to the plane of feed in amounts substantially equal to the movement of the contacting end of the tracer, said last-named power operable means comprising a rotatable head having a fluid reciprocable member operatively connected for shifting said cutter spindle, and

16

a control valve in said tracer head operated by oscillation of said tracer in said radial plane for automatically controlling the shifting of said fluid reciprocal member.

17. In a profiling machine having a tool and work support, power operable means for effecting relative feeding movement between said supports, and a rotary tracer head mounted on the tool support for controlling the direction of said feeding movement, the combination of a cutter spindle, a pair of superimposed slides supporting said cutter spindle on the tool support, a rotatable head having a radially movable member operatively connected to said slides, fluid operable means for rotating said tracer head and said rotatable head, a first valve in said tracer head operated by lateral movement of said tracer finger for governing said fluid operable means, a second fluid operable means for shifting said radially movable member, and a second valve in said tracer head responsive to oscillation radial of the tracer finger to control said second-named fluid operable means.

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