July 20, 1954 O. E. STAPLES 2,684,016

HOBBING MACHINE

Filed April 16, 1948 11 Sheets-Sheet 1

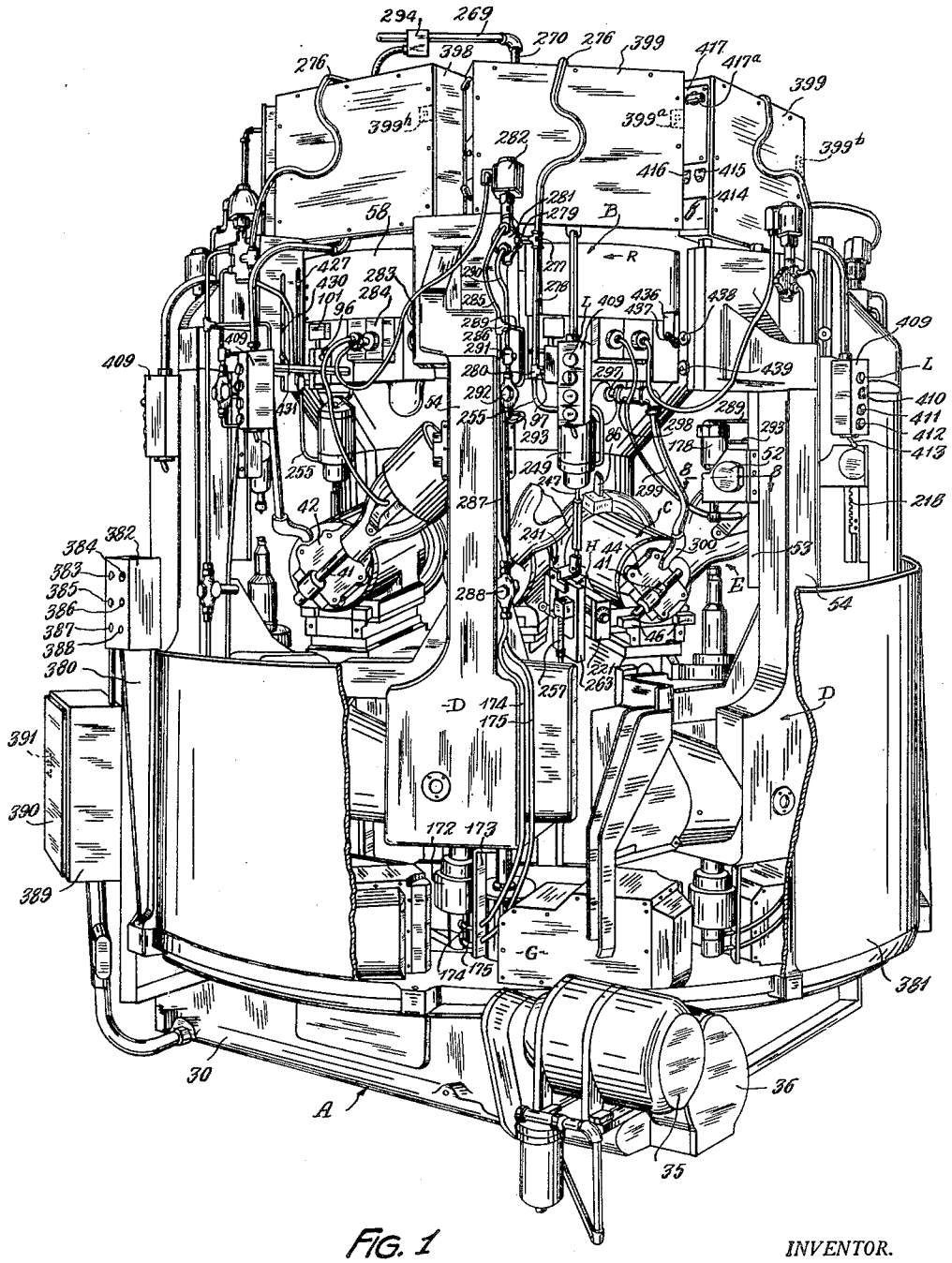


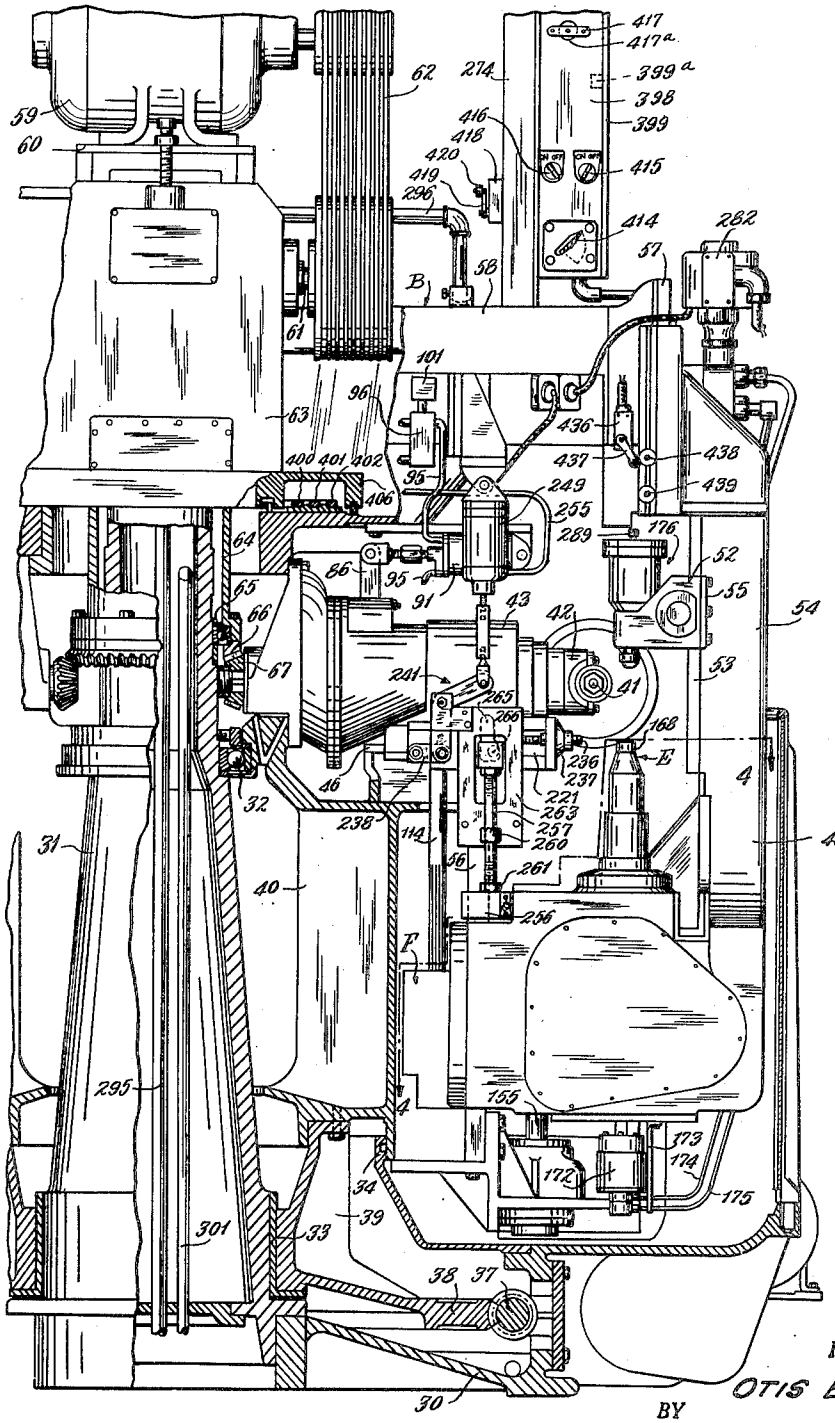
FIG. 1

INVENTOR.
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Kurtis, Hudson, Boughton & Williams
ATTORNEYS

July 20, 1954 O. E. STAPLES 2,684,016

HOBBING MACHINE

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INVENTOR.
OTIS E. STAPLES
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FIG. 2 Kurtz, Hudson, Boughton & Williams
ATTORNEYS

July 20, 1954 O. E. STAPLES 2,684,016

HOBBING MACHINE

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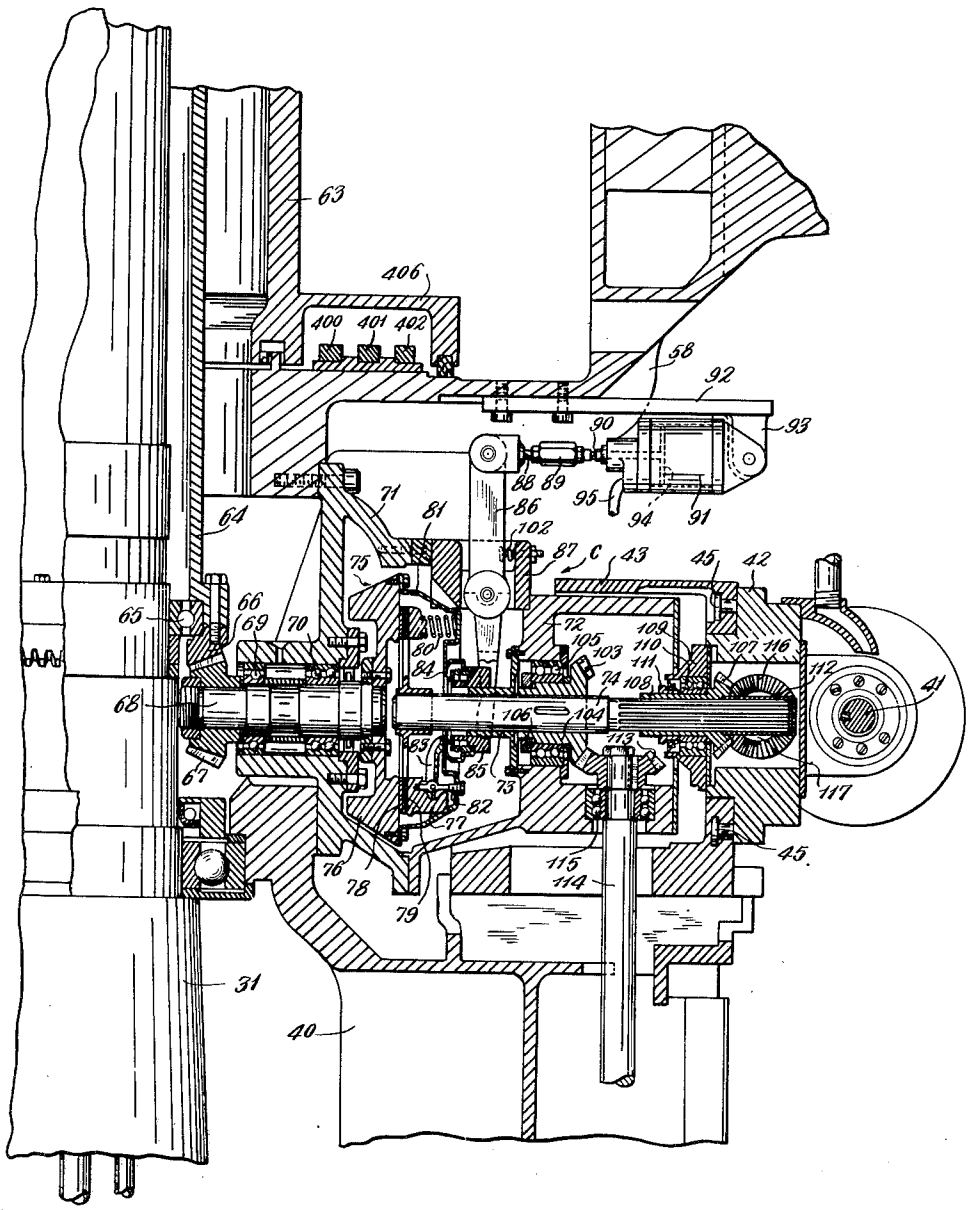


FIG. 3

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July 20, 1954 O. E. STAPLES 2,684,016

HOBBING MACHINE

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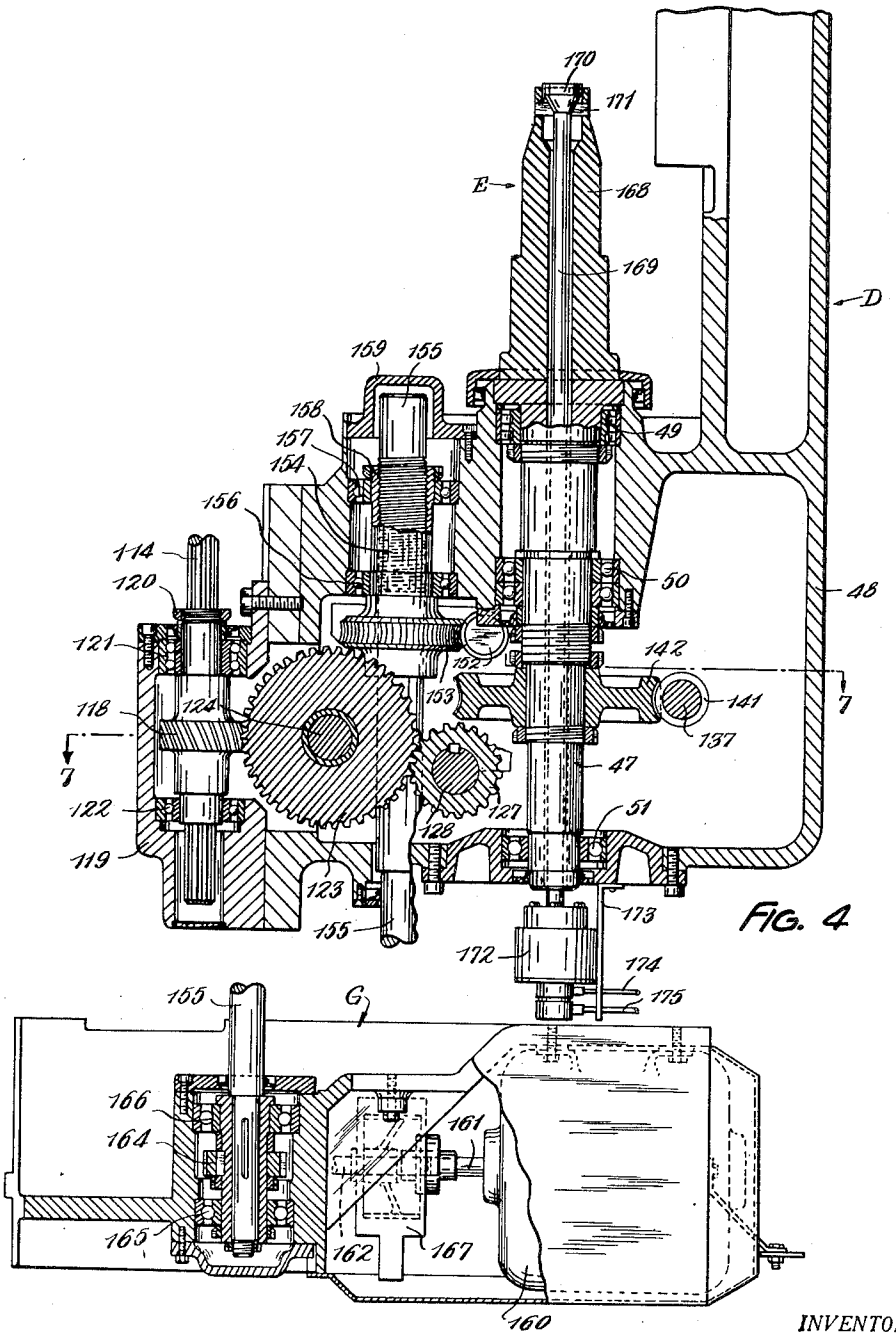


FIG. 4

FIG. 5

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July 20, 1954 O. E. STAPLES 2,684,016

HOBBING MACHINE

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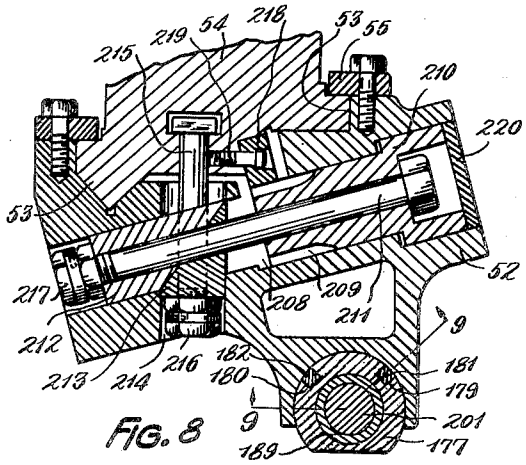


FIG. 8

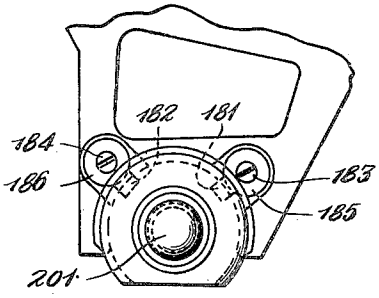


FIG. 10

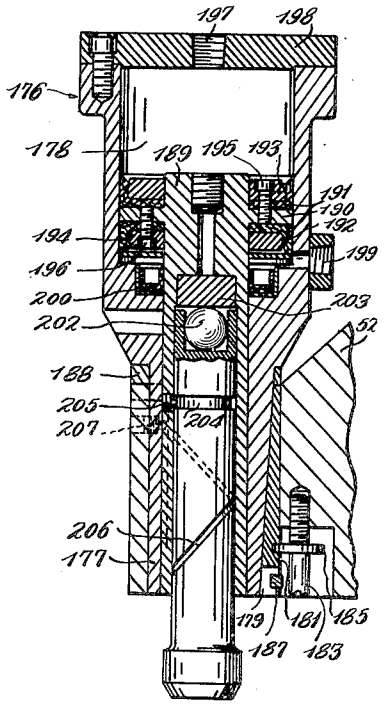


FIG. 9

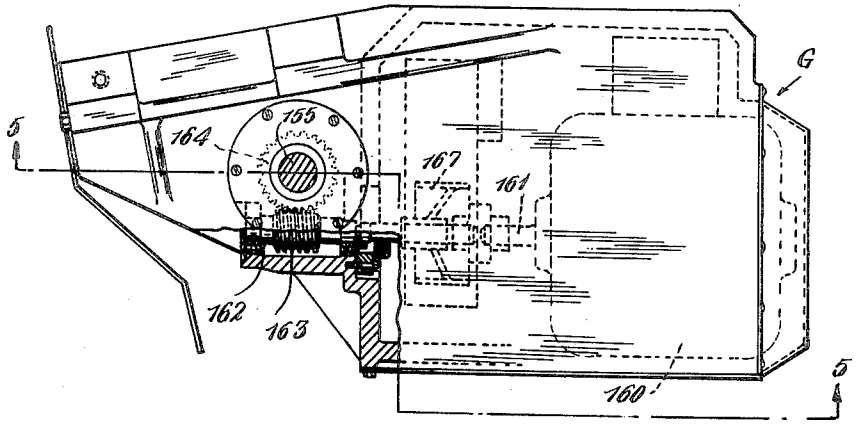


FIG. 6

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July 20, 1954

O. E. STAPLES

2,684,016

HOBBING MACHINE

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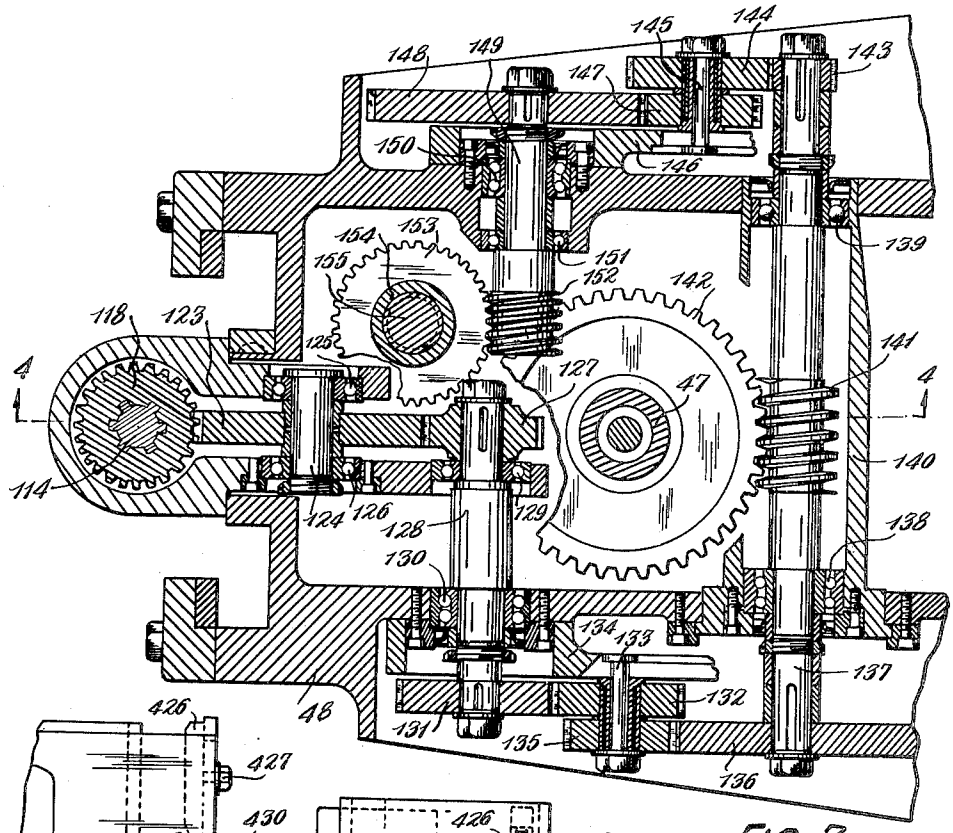


FIG. 7

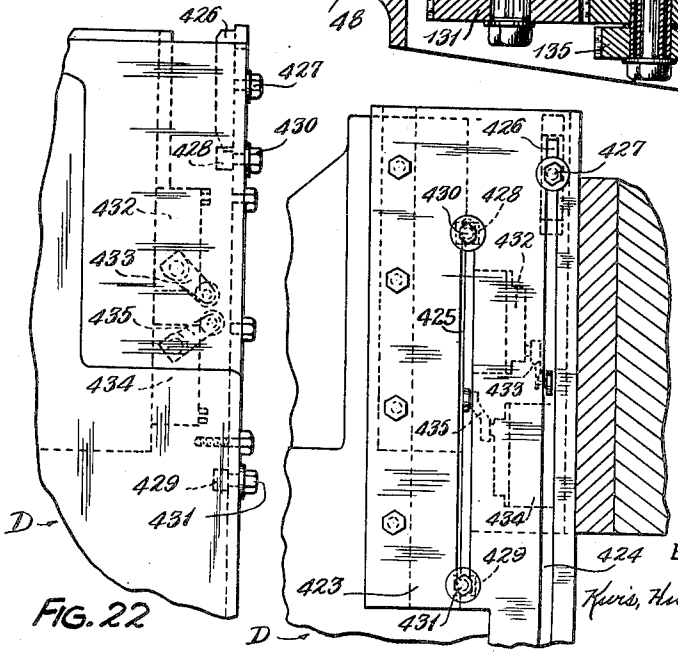


FIG. 22

FIG. 23

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July 20, 1954 O. E. STAPLES 2,684,016

HOBBING MACHINE

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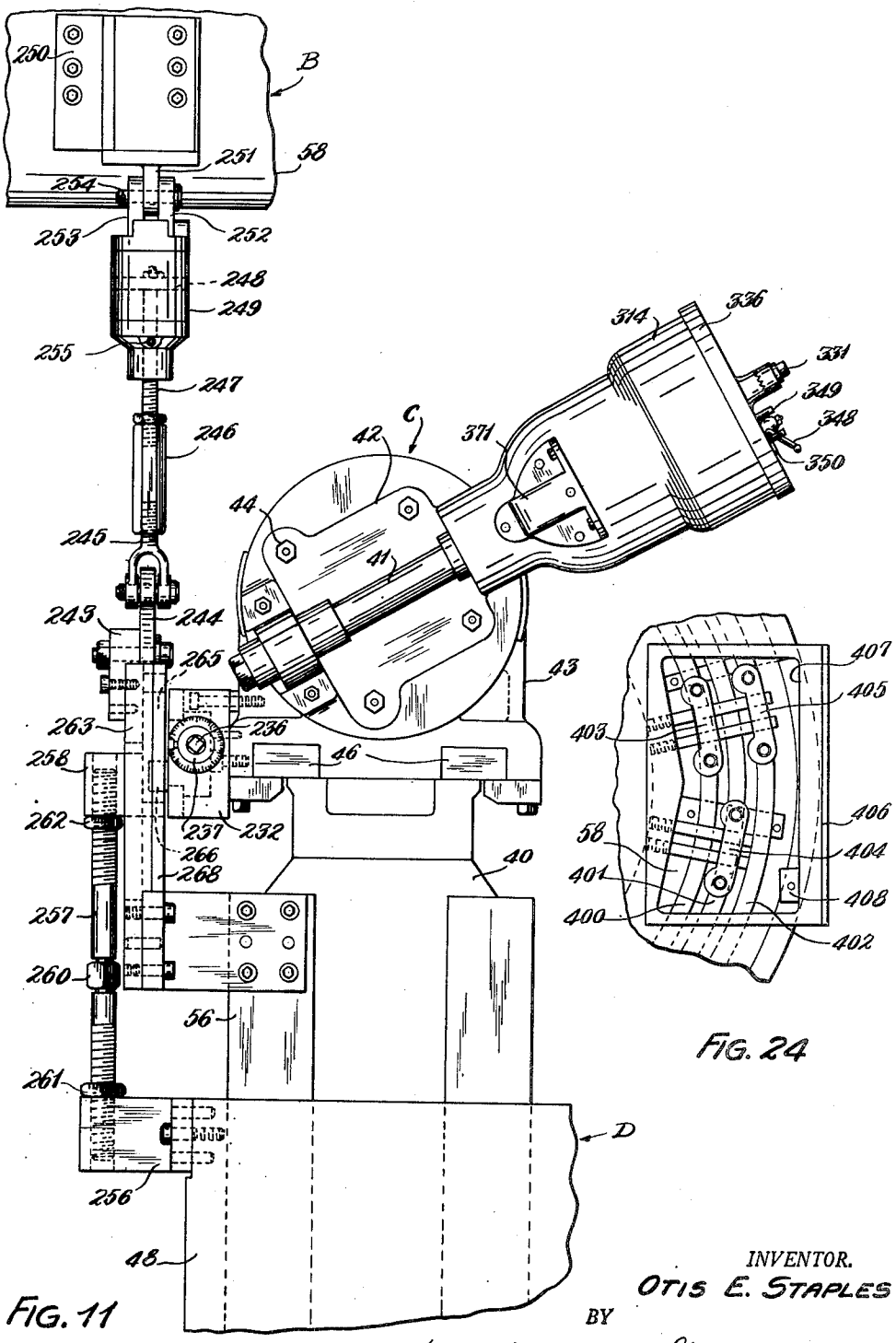


FIG. 11

FIG. 24

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July 20, 1954 O. E. STAPLES 2,684,016

HOBBING MACHINE

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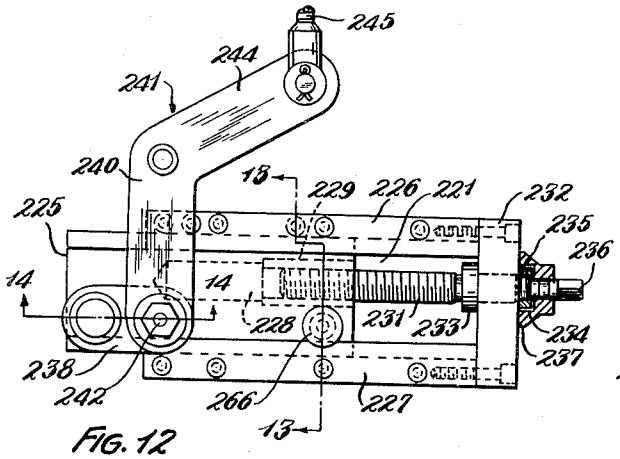


FIG. 12

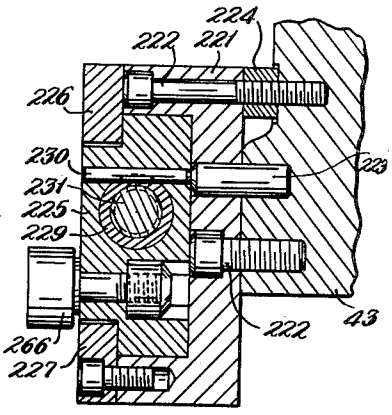


FIG. 13

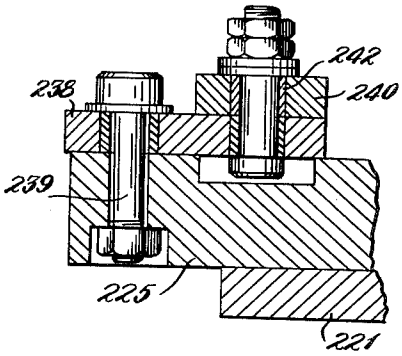


FIG. 14

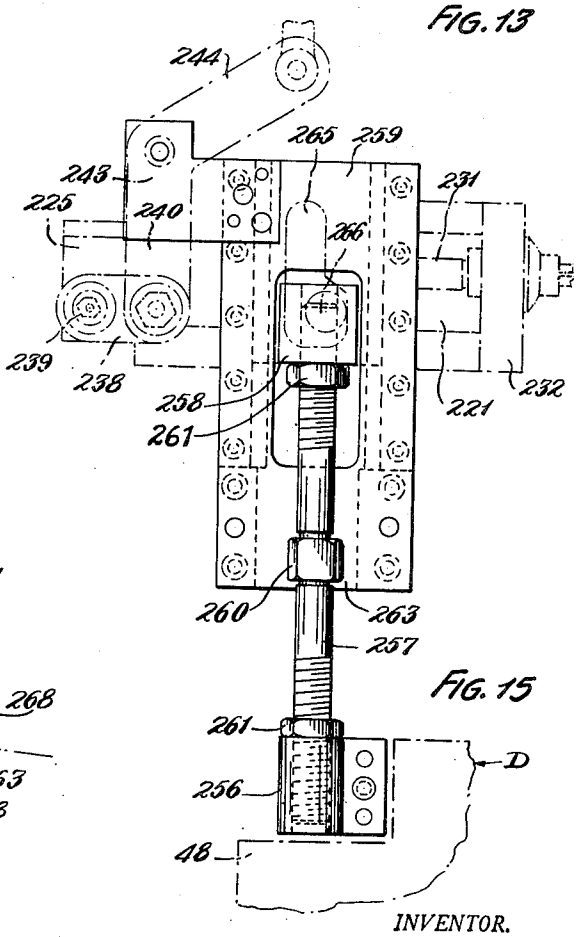


FIG. 15

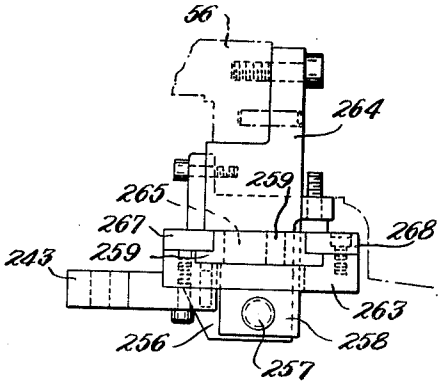


FIG. 16

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HOBBING MACHINE

Filed April 16, 1948 11 Sheets-Sheet 9

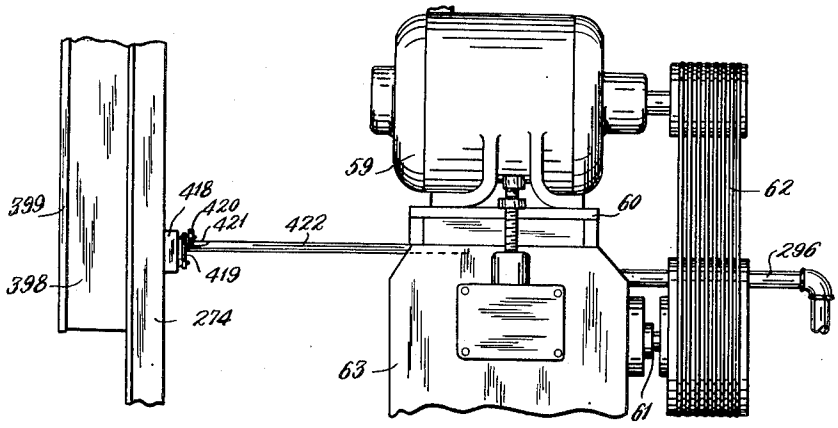


FIG. 17

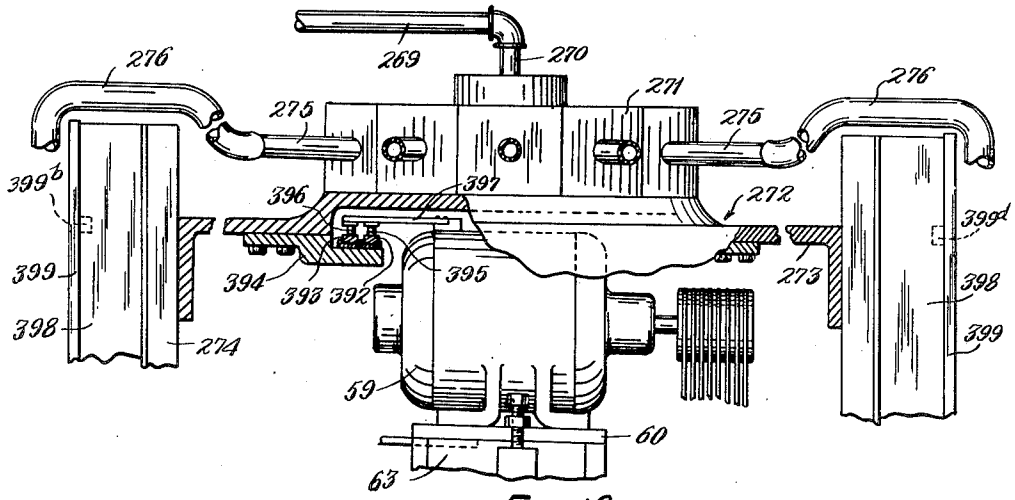


FIG. 18

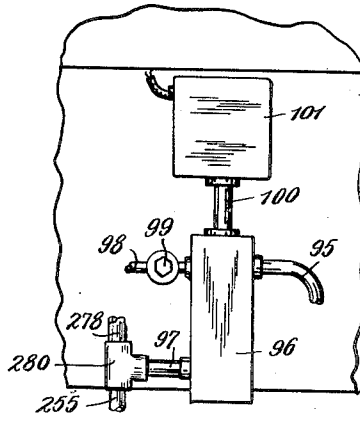


FIG. 19

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HOBBING MACHINE

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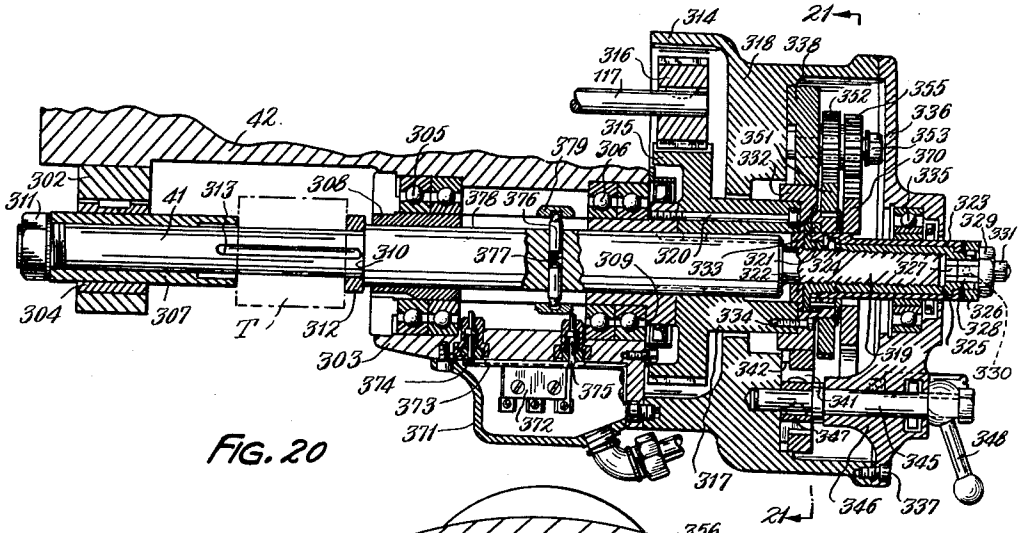


FIG. 20

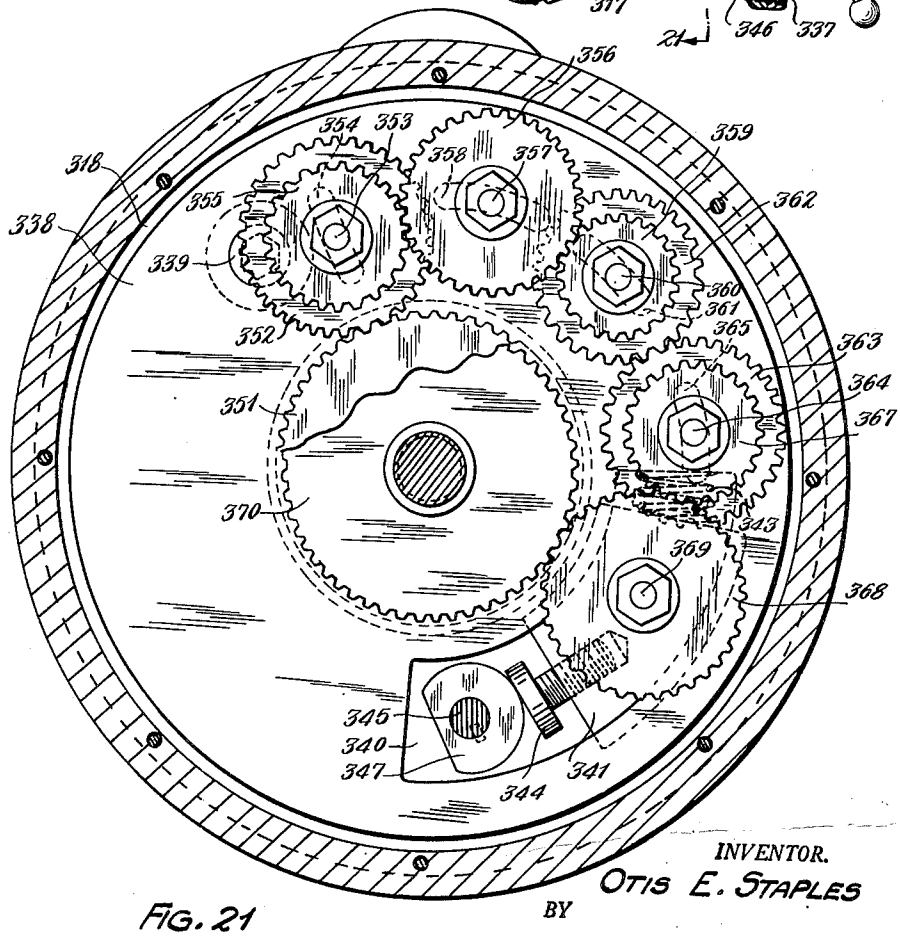


FIG. 21

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HOBBING MACHINE

Filed April 16, 1948 11 Sheets-Sheet 11

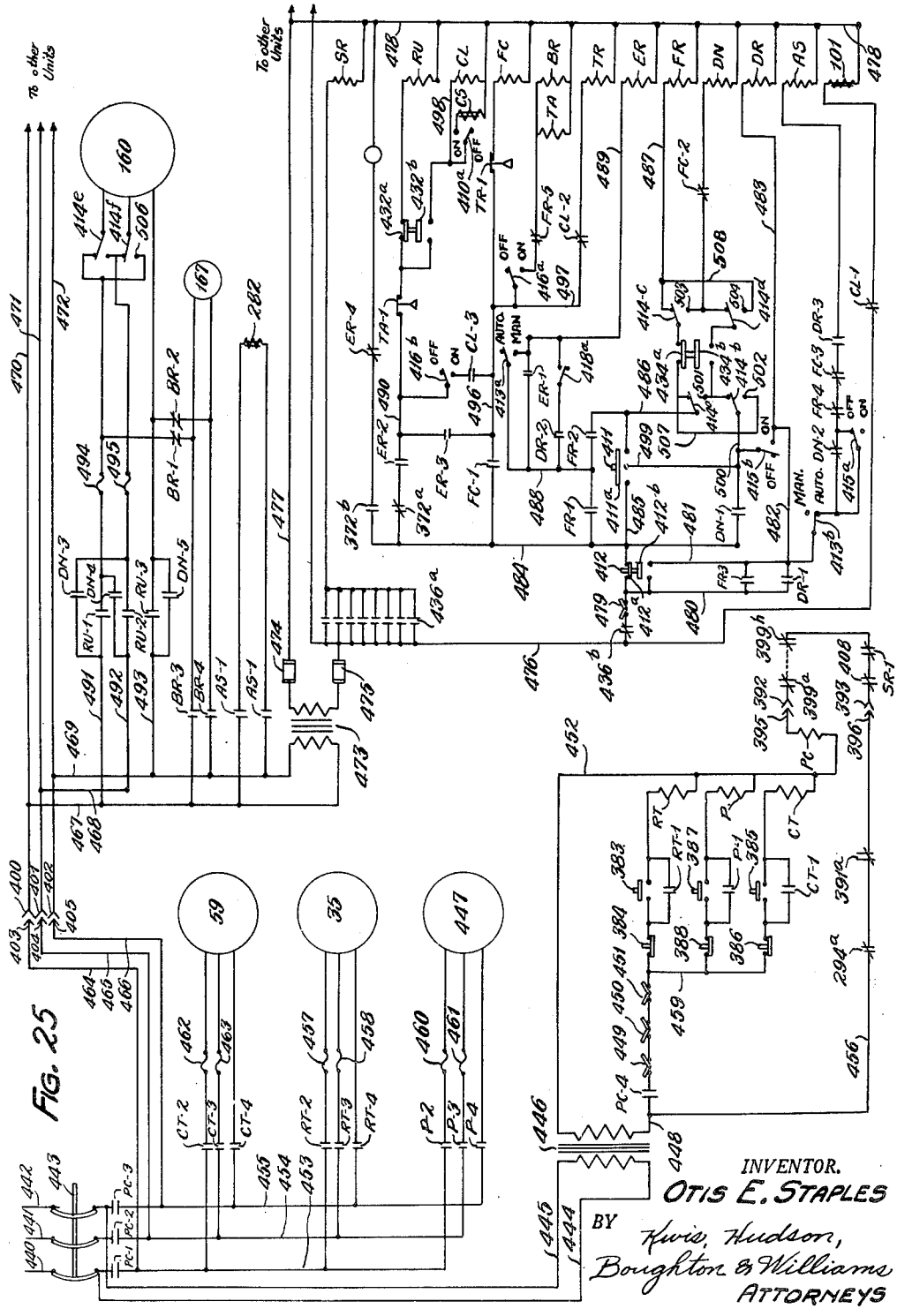


FIG. 25

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Patented July 20, 1954

2,684,016

UNITED STATES PATENT OFFICE

2,684,016

HOBBING MACHINE

Otis E. Staples, Euclid, Ohio, assignor to The Cleveland Hobbing Machine Company, Euclid, Ohio, a corporation of Ohio

Application April 16, 1948, Serial No. 21,493

13 Claims. (Cl. 90—4)

1

The present invention relates to machine tools and, more particularly, to a hobbing machine having means for producing "in-feed" of the hob relative to the work.

An object of the invention is the provision of a novel means for producing "in-feed" of the cutting tool of a gear cutting or hobbing machine, which means may be either incorporated in the machine when built or attached to existing machines without the necessity of extensive modifications thereof.

Another object of the invention is the provision of an improved gear cutting or hobbing machine having means for producing "in-feed" of the cutting tool or hob, which means comprises a mechanical interconnection between the movable supports for the tool and work spindles whereby the "in-feed" of the tool is accurately controlled by the relative movement between the tool and work spindle longitudinally of the axis of the latter.

A further object of the invention is the provision of an improved gear cutting or hobbing machine having means for producing "in-feed" of the cutting tool or hob, which means comprises fluid pressure means continuously urging the tool spindle to move in a direction extending transversely of the work spindle and means carried by the support for the work spindle, and operating by virtue of the relative vertical movement between the tool and work spindles, to control the movement of the tool spindle in response to the action of the fluid pressure means and to move said tool spindle in the reverse direction in opposition to the action of said fluid pressure means.

The invention further resides in certain novel features of construction, and combinations and arrangements of parts, and further objects and advantages thereof will be apparent to those skilled in the art to which it pertains from the following description of the present preferred embodiment thereof described with reference to the accompanying drawings in which similar reference characters represent corresponding parts throughout the several views, and in which:

Fig. 1 is a perspective view of a rotatable turret-type hobbing machine embodying the present preferred form of the invention, certain portions being broken away and others omitted for the purpose of clarity;

Fig. 2 is an enlarged, fragmentary view of the machine shown in Fig. 1, the view being partly in section and partly in elevation with the section being taken approximately on the centerline

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of the machine, the novel "in-feed" mechanism being shown in side elevation;

Fig. 3 is an enlarged sectional view of hob head and associated parts shown in Fig. 2 illustrating the drive for the tool or hob and the drive for feeding and rotating the work spindle of one unit of the machine;

Fig. 4 is a vertical sectional view through the lower portion of the work head illustrated in Fig. 2, the view being taken substantially on the lines 4—4 of Figs. 2 and 7;

Fig. 5 is a side view, partly in section and partly in elevation, of the rapid traverse mechanism for a single unit of the machine, the section being taken substantially on the line 5—5 of Fig. 6 and an additional portion of the housing being broken away to show portions of the rapid traverse motor and associated brake;

Fig. 6 is a top view of the rapid traverse mechanism illustrated in Fig. 5 with portions broken away to more clearly show the construction;

Fig. 7 is a sectional view through the lower portion of the work head, the view being taken substantially on the irregular section indicating line 7—7 of Fig. 4, with certain parts broken away to more clearly illustrate the gearing connections;

Fig. 8 is a fragmentary sectional view through one of the tailstock supporting means, the view being taken substantially on the line 8—8 of Fig. 1;

Fig. 9 is a sectional view through one of the fluid operated tailstock mechanisms and a portion of the tailstock supporting means, the section being taken substantially on the section indicating line 9—9 of Fig. 8;

Fig. 10 is a bottom elevational view of one of the tailstock mechanisms, only a portion of the tailstock supporting means illustrated in Fig. 8 being shown;

Fig. 11 is an enlarged, fragmentary, front elevational view of one of the tool or hob heads of the machine and of the novel "in-feed" mechanism attached thereto;

Fig. 12 is a detached, side elevational view of that portion of the novel "in-feed" mechanism which is connected with a tool or hob head;

Fig. 13 is an enlarged sectional view, taken substantially on the section indicating line 13—13 of Fig. 12, with the actuating arm removed and showing the connection of a portion of the "in-feed" mechanism to the tool or hob head which is controlled thereby;

Fig. 14 is an enlarged, fragmentary, sectional view taken substantially on the section indicating line 14—14 of Fig. 12.

Fig. 15 is a detached, side elevational view of

the cam slide assembly forming a part of the novel "in-feed" mechanism, the connections therewith to other portions of the mechanism being indicated in dot-dash lines;

Fig. 16 is a top elevational view of the portions of the mechanism illustrated in full lines in Fig. 15;

Fig. 17 is a fragmentary, side elevational view of a portion of the interior of the machine adjacent the top thereof illustrating the stationary cam for actuating a switch mounted on the back of each unit of the machine;

Fig. 18 is a fragmentary view, partly in side elevation and partly in section, illustrating the air distributing means and one set of collector rings mounted at the top of the machine;

Fig. 19 is a fragmentary front elevational view of one of the fluid pressure control means for controlling actuation of the clutch illustrated in Figs. 2 and 3;

Fig. 20 is a longitudinal sectional view through one of the tool or hob heads with certain members shown in elevation;

Fig. 21 is a sectional view substantially on the line 21—21 of Fig. 20;

Fig. 22 is a fragmentary front elevational view of the top portion of one of the work heads of the machine illustrated in Fig. 1 showing, in dotted lines, certain of the switches operated by movement of the work head;

Fig. 23 is a fragmentary side view of the top portion of one of the work heads of the machine, the view being partly in elevation and partly in section and representing the right-hand side of Fig. 22;

Fig. 24 is a fragmentary top plan view of a portion of the housing for the collector rings illustrated in Figs. 2 and 3, the cover plate for the brushes being removed; and

Fig. 25 is a simplified wiring diagram of a portion of the electrical circuits for the machine.

The invention is illustrated as embodied in a rotatable turret type hobbing machine similar to that illustrated in U. S. Patent 2,629,291, issued February 24, 1953, on my copending application, Serial No. 757,256, filed June 26, 1947, in which many of the novel features herein illustrated and described are specifically claimed.

The general nature of the machine is illustrated in Fig. 1 of the drawings and comprises a stationary frame A on which a turret B is mounted for rotation in the direction indicated by the arrow R. At spaced points about the turret are mounted a plurality of identical tool or hob heads C and adjacent each tool head the turret carries a work head D, the latter being slidably supported for vertical movement relative to the corresponding tool head. Each tool head is provided with mechanism for supporting and rotating a hob or other tool, the tool being adapted to be rotated about an axis extending transversely of the vertical movement of the adjacent work head. In addition, each tool head C includes mechanism for producing a relatively slow axial movement of the hob or other tool while the latter is rotating. Each work head includes a means E for supporting and rotating a workpiece about a substantially vertical axis, and mechanism F for producing a feeding movement of the work head vertically during a cutting operation. This rotation of the workpiece and the feeding movement thereof are in timed relationship to the rotation of the hob or other tool. The machine also includes a rapid traverse mechanism G for each work head to move the latter at a rapid rate to bring the work into cutting relationship with the hob or other tool and to return the work head to its initial position after the cutting operation has been completed. Each tool, or hob head, work head, work gripping means and rapid traverse mechanism, which are associated together, form an operational or hobbing unit and are, at times, so referred to in the subsequent description and the subjoined claims. In addition to these mechanisms, each operational unit of the machine is provided with a novel mechanism H for producing movement of the hob head transversely of the vertical movement of the work head under positive mechanical control of the latter. This movement of the hob head is termed "in-feed" and, while not limited thereto, is especially useful when employing the machine to cut gears on cam shafts or the like.

In operating the machine, the turret thereof is rotated so that the tool and work heads successively pass a definite position known as the loading station where workpieces may be inserted and removed, the hobbing or other machining operation being effected as the turret continues to rotate and is completed by the time a given operational unit has returned to the loading station. As will hereinafter appear, the novel "in-feed" mechanism automatically causes "in-feed" of the hob or other cutting tool of each unit at a predetermined time during the rotation of the turret. This is effected by a mechanical interconnection between the movable supports for the tool and work spindles of each unit so that the "in-feed" is accurately controlled by the relative vertical movement between the spindles.

Referring now in more detail to the drawings, Figs. 1 and 2 illustrate the frame A as comprising a base 30 and a central, vertically extending column 31 uniting with the base and forming the main support for the machine. The turret B is rotatably supported upon the column and base by bearings 32, 33, and 34. Rotation of the turret B is effected by means of a motor 35 which operates through a suitable reduction gearing 36 to rotate a worm 37 and thereby drive the worm wheel 38, which is of large diameter and may be integral with or attached to a flange member 39. The member 39 is secured by bolts, or other suitable means, to the lower part of a vertically extending annular member 40, which forms the main frame of the turret B.

Each of the tool or hob heads C comprises a tool or hob spindle 41 rotatably supported by a spindle supporting member 42, which is in turn carried by a slidable head member 43 (see also Fig. 3). Each spindle supporting member 42 is angularly adjustable, relative to its head member 43, about an axis normal to the axis of the hob spindle 41 and is secured to the head member 43 in any adjusted position by bolts 44, the heads of which engage within circular or arcuate T-shaped openings 45 in the front face of the member 43. The head members 43 are slidably supported by horizontal ways 46 on the turret member 40, the head members being moved therealong in timed relationship with the vertical movement of the corresponding work head as hereinafter described.

Each of the work heads D is provided with a work holding and rotating means E which includes a work spindle 47 (see Fig. 4) rotatably supported in the lower portion 48 of the work head by antifriction bearings 49, 50 and 51. The

upper end of each work spindle is provided with a chuck and each work head is further provided with a tail slide 52, slidably supported by ways 53 on the vertical portion 54 of the work head D, the several slides 52 each being held in any adjusted position on the ways by suitable clamping means 55 which are illustrated as comprising conventional clamping plates and bolts. The head members D are slidably supported on vertical ways 56, provided on the turret member 40, and on vertical ways 57, provided on a cap member 58 which is integral with, or secured to, the top of the turret member 40 in any suitable manner. The work head members D are moved vertically along the ways 56 and 57 by mechanism to be hereinafter described.

The tool and work spindles, 41 and 47, respectively, are rotated in predetermined timed relationship by a motor 59, hereinafter referred to as the "cut" motor, which is supported upon an adjustable platform 60 on top of the column 31. This motor is operatively connected to a shaft 61 through a flexible drive 62, the shaft 61 being connected by suitable gearing mechanism, contained within the housing 63 forming a part of the column 31, to a sleeve 64 which is rotatably supported by bearings 65 on the vertical column 31. A bevel gear 66 is attached to the lower end of the sleeve 64, by means of bolts or the like, and the gear 66 meshes with a plurality of spaced bevel pinions 67, there being one bevel pinion 67 for each hobbing unit. Each pinion 67 is keyed to a short shaft 68 (see Fig. 3) which is rotatably supported by bearings 69 and 70 in the rear portion of a two-part housing 71 attached to the member 40 and cap portion 58 of the turret B adjacent the edges of an opening therethrough. The drives for the various hobbing units from the gear 66 through the gears 67 are duplicates and, therefore, only one will be described in detail.

As shown in Fig. 3, the forward portion of the housing 71 extends into the hollow interior of the head member 43 and this portion of the housing is provided with an internal shoulder or flange 72 to the rear of which is connected a sleeve member 73. A shaft 74 is journalled in the sleeve member 73 and extends forwardly and rearwardly therebeyond, this shaft being selectively, operatively connected with the shaft 68 by means of a friction plate clutch 75. This clutch is of conventional design and comprises a driving member 76, connected to the shaft 68, and a driven member 77 which is connected to the shaft 74. The cooperating faces of the members 76 and 77 are provided with friction material 78 and 79, respectively, and are normally forced into engagement by a plurality of spaced compression coil springs 80 exerting force between the rear of the driven member 77 and a housing member 81 connected with the driving member.

The housing member 81 is provided with a plurality of axially extending rods 82 which are slidably received in bosses integral with the rear face of the driven member 77, only one rod and cooperating boss being shown. Pivoted to each rod 82 is a radially extending actuating lever 83 which is urged to the illustrated position by the action of the springs 80 on the driven member 77 since the lower portion of each lever engages a cam surface in a recess provided in each of the integral bosses on the driven member. This action may be assisted, if desired, by providing each lever 83 with a supplemental spring, not shown. The upper portions of the levers 83 extend adjacent the shaft 74 and are adapted to be rocked in a counterclockwise direction by an annular member 84 which is rotatably supported upon a collar 85 slidably supported upon the sleeve 73. The collar 85 is straddled by the bifurcated lower end of an actuating member or lever 86, the forward faces of the bifurcated portion bearing against a cooperating surface on the sleeve 85. The lever 86 is pivoted intermediate its ends to a bracket member 87 which is mounted in an opening in the forward portion of the housing 71.

The upper end of lever 86 is pivotally connected to a rod 88 which has an adjustable connection 89 with a piston rod 90. The piston rod 90 extends into a cylinder 91 which is supported upon the cap member 58 of the turret by means of a plate 92 having a depending bracket 93. The inner end of the piston rod 90 is provided with a piston 94 which is adapted to be actuated to the right, as shown in Fig. 3 by fluid pressure admitted to the rear end of the cylinder through a flexible pipe or hose 95, the forward portion of the cylinder being provided with an exhaust port, not shown, communicating the area in front of the piston with the atmosphere.

The flow of fluid under pressure to the cylinder 91 is controlled by a two-way valve 96 (see Figs. 1 and 19) mounted upon the cap member 58 of the turret B. As shown in Fig. 19, the pipe or hose 95 is connected to this valve 96 which is also provided with a fluid pressure supply pipe or hose 97 and an exhaust port 98, the latter having an adjustable orifice, such as a needle valve or the like, controlled by an adjusting screw 99. The movable member of the valve 96 is connected by an actuating member or rod 100 to the armature of an electrically operated solenoid 101, the valve being so formed that when the solenoid is energized communication is established between the fluid supply pipe or hose 97 and the pipe or hose 95 thus supplying fluid pressure to the cylinder 91. Consequently, the piston 94 is forced to the right, as viewed in Fig. 3, rocking the lever 86 clockwise. This causes the collar 85 and annular member 84 to move axially to the left rocking the levers 83, and the lower ends of the latter force the driven member 77 to the right, against the action of the springs 80, disengaging the clutch.

When the solenoid 101 is deenergized the movable member of the valve 96 is actuated to interrupt the communication between pipes or hoses 97 and 95 and to establish communication between the pipe or hose 95 and the exhaust port 98. Hence, the springs 80 of the clutch act through the driven member 77, levers 83, annular member 84 and collar 85 to rock the lever 86 in a counterclockwise direction, this action being assisted by a compression spring 102 mounted upon the bracket 87 and bearing against the lever 86 above its pivot. The counterclockwise movement of the lever 86 moves the piston 94 to the left, as viewed in Fig. 3, thus discharging the fluid in the cylinder 91 through the pipe or hose 95, valve 96 and the exhaust port 98. The adjustable orifice in the port 98 controls the rate of discharge of the fluid and hence the rate of engagement of the driven member 77 of the clutch with the driving member 76, under the action of the springs 80, thus preventing grabbing. The manner in which the solenoid 101 is energized and deenergized during the working cycle of the machine to effect operation of the clutch 75 will be hereinafter described.

A bevel gear 103, provided with an integral

sleeve 104, is keyed to the shaft 74 intermediate the ends of the latter, the sleeve 104 being journalled by bearings 105 in the shoulder 72 of forward portion of the housing 71. The sleeve 104, and hence the gear 103, are held against axial displacement by a nut 106, threaded upon a reduced end of the sleeve and engaging the adjacent end of the inner race for the bearings 105.

The outer end of the shaft 74 is splined and provided with a bevel gear 107 which is slidably keyed to the splined portion of the shaft. The gear 107 is provided with an integral sleeve portion 108 which is rotatably supported in a member 109 by bearings 110, the gear being held against longitudinal displacement relative to its bearings by a nut 111 threaded upon the sleeve portion 108 and the member 109 being attached to the spindle supporting member 42. The outer face of the gear 107 is preferably provided with a cylindrical member 112 which surrounds the outer end of shaft 74 to protect the latter.

The bevel gear 103 meshes with a bevel gear 113 connected with the upper end of a vertical shaft 114, the latter being journalled by bearings 115 in an opening in the lower side of the forward portion of the housing 71. This shaft 114 forms a part of the work spindle rotating and feeding mechanism, which will be subsequently described in detail. The gear 107 is in mesh with another bevel gear 116 mounted upon a shaft 117 and forming a part of the drive for rotating and axially moving the tool or hob spindle 41. It will be apparent therefore, that when the clutch 75 is engaged, the shaft 74 will be rotated by the cut motor 59 through the gears 66, 67, shaft 68, and clutch 75 thus driving the shaft 114 for rotating and feeding the work spindle, as hereinafter described, the shaft 117 also being rotated for rotating and axially moving the tool spindle. Conversely, disengagement of the clutch 75 interrupts rotation of the shaft 74 simultaneously stopping the mechanism driven thereby.

As shown in Fig. 4, the lower end of shaft 114 is splined and passes through a helical gear 118 which is keyed to the splined portion of the shaft 114 to be rotated thereby, the splining permitting the gear to be slid axially along the shaft. The gear 118 is positioned within a housing 119, attached to the lower portion 48 of the work head D, the gear being prevented from axial displacement relative to the housing by means of a nut and washer assembly 120 which engage one side of the inner race for the antifriction bearings 121 in which the shaft 114 is journalled, the other side of the inner race of these bearings being in engagement with a shoulder formed by a sleeve-like portion of the gear 118. The lower end of the shaft 114 extends into a bore of the housing 119 and is journalled by antifriction bearings 122, which are positioned between a cylindrical sleeve extension of the gear 118 and the enlarged upper end of the aforementioned bore in the housing 119.

The helical gear 118 meshes with another helical gear 123 mounted upon a stub shaft 124, the latter being journalled in a portion of the housing 119 by means of antifriction bearing 125, 126 (see Fig. 7). The gear 123 is also in mesh with a helical gear 127 which is keyed to one end of a shaft 128, the latter being rotatably supported by antifriction bearings 129, 130 in the housing 119 and in the portion 48 of the work head, respectively. The other end of the shaft 128 carries a spur gear 131 for rotation therewith, and the gear 131 meshes with a spur gear 132 rotatably mounted upon a stub shaft 133, the latter being supported by a bracket 134 connected with the portion 48 of the work head. The shaft 133 is also provided with a spur gear 135, connected to rotate with the spur gear 132, and the gear 135 meshes with a spur gear 136 keyed to one end of a worm shaft 137 the latter being journalled by suitable antifriction bearings 138 and 139 in a sleeve-like support 140 mounted in the portion 48 of the work head D. Intermediate its ends, and within the interior of the portion 48 of the work head, the shaft 137 carries a worm 141 which meshes with a worm wheel 142 secured to the work spindle 47. Therefore, when the clutch 75 is engaged, the motor 59 will effect rotation of shaft 114 thereby rotating the work spindle 47 through the gears 118, 123, 127, 131, 132, 135, 136, worm 141 and worm wheel 142.

The end of the worm shaft 137, opposite to the end on which is attached the gear 136, is provided with a pinion 143 which meshes with a gear 144 rotatably mounted upon a stub shaft 145, the latter being supported by a bracket 146 connected to portion 48 of the work head. The shaft 145 also supports a gear 147 which is mounted to rotate with the gear 145. The gear 147 meshes with a gear 148 which is keyed to a shaft 149, this shaft being journalled by antifriction bearings 150 and 151 in the portion 48 of the work head D. The inner end of the shaft 149 is provided with a worm 152, which drives a worm wheel 153 forming a part of a feed nut 154. As shown in Fig. 4, the feed nut 154 comprises a cylindrical sleeve-like extension of the worm wheel 153 and is internally threaded to cooperate with the threads on a feed screw or shaft 155. The sleeve-like portion of the feed nut is journalled in a suitable bore-like opening within the portion 48 of the work head member by antifriction bearings 156 and 157, the nut being held against axial displacement relative to its bearings by means of an integral shoulder cooperating with bearing 156 and a nut 158 cooperating with the bearing 157. The bore in which the feed nut and screw are located may be closed by a suitable cap 159 to prevent the entrance of dirt, chips or the like.

The construction is such that when the clutch 75 is engaged, the motor 59 will drive the shaft 114 thereby rotating the worm shaft 137, in the manner previously described, and this rotation of the shaft 137 operates through the gears 143, 144, 147, 148, worm 152, and worm wheel 153, forming a part of the feed nut 154, to cause the latter to rotate relative to the feed screw or shaft 155. Since the feed nut 154 is supported against axial movement, this rotation causes the said nut, and hence the entire work head, to move vertically as the nut threads along the screw or shaft 155. As previously mentioned, the lower end of the shaft 114 is splined so that the gear 118 may move therealong during this operation. Moreover, the rotation of the work spindle 47, and the vertical movement thereof, are in predetermined timed relationship and may be simultaneously started and stopped by the operation of the single clutch 75. This vertical movement of the work head and work spindle is that which is commonly known as a "feeding movement" and is effected at a relatively slow rate while the hob or other tool supported upon the spindle 41 performs a cutting or hobbing operation upon the work carried by the work spindle 47.

Each work head D may be rapidly moved in a vertical direction by means of a separate rapid traverse mechanism G (see Figs. 5 and 6) which

includes a motor 160, the shaft 161 of which is connected to a worm shaft 162 upon which is mounted a worm 163. The worm 163 cooperates with a worm wheel 164 connected for rotation with the lower end of the feed screw or shaft 155, the lower end of the latter being supported by suitable antifriction bearings 165 and 166 in the housing for the rapid traverse mechanism G. Hence, when the motor 160 is rotated, the feed screw 155 is rotated relative to the feed nut 154, thereby causing vertical movement of the work head D at a relatively rapid rate, hereinafter referred to as rapid traverse. The motor 160 is preferably reversible and its shaft 161, or the worm shaft 162 connected thereto, is provided with an electrically operated brake 167 which is spring actuated to normally engage the shaft for preventing rotation of the latter and of the feed screw 155, the brake being provided with an electromagnet which releases the brake when energized. It will be observed that there is a separate rapid traverse motor 160 for each of the work heads carried by the machine so that the rapid traverse movement of each work head is independent of that of all the others. The vertical movement of the work heads is selectively effected at either the feed rate by motor 59, or at the rapid traverse rate by motor 160, as determined by actuation of switches in an electrical circuit hereinafter described.

Each of the work heads D of the machine is provided with a fluid operated work holding means E for securing a workpiece to the work spindle. In the illustrated machine, this means comprises an internal chuck 168 secured to the upper end of the work spindle 47 for rotation therewith. As shown in Fig. 4, the body of this chuck and the work spindle 47 are provided with aligned bores through which a chuck actuating rod 169 extends, the upper end of the rod being provided with an enlarged portion having a substantially conical surface 170 slidable within a counterbore provided at the upper end of the chuck. Extending radially outward through the side walls of the upper portion of the chuck are a plurality of work-gripping fingers 171 the fingers being slidable radially and having inclined camming surfaces on their inner ends for cooperation with the conical surface 170. The construction is such that, when the rod 169 is moved downwardly within the chuck 168, the fingers 170 are forced radially outwardly to engage a workpiece W and securely hold the latter.

Movement of the rod 169 is effected by a fluid operated means which comprises a cylinder 172 attached to the lower portion 48 of the work head D by a suitable plate or bracket 173. The lower end of the rod 169 extends within the cylinder 172 and is provided therein with a piston, not shown, which is adapted to be moved vertically in either direction by fluid under pressure supplied through pipes or hoses 174 and 175, which are connected to a source of fluid under pressure in a manner hereinafter described. Hence, when fluid pressure is allowed to enter the cylinder 172 through one of the pipes, the rod 169 is lowered thereby actuating the fingers 171 into work-gripping position. Reversing the direction of application of fluid pressure to the pipes 174 and 175, and hence to the cylinder 172, elevates the rod 169 thereby releasing the fingers 171 and freeing the work for ready removal. The internal construction of the fluid operated means, generally designated as a cylinder 172, is substantially like that employed for the tail stock mechanism about to be described.

Referring now to Figs. 2, 8, 9 and 10, it will be seen that the tail stock mechanism for each unit of the machine, generally designated 176, is supported by the tail slide 52 upon the ways 53 of the vertical portion 54 of work head D, the tail slide being provided with clamping plates and screws 55 cooperating with the ways 53 (see Fig. 8) so that the tail slide and the tail stock mechanism may be moved along the ways to a desired position and secured to the ways at that position. The tail slide 52 is provided, on its outer end, with a bore in which is positioned the lower, reduced diameter portion 177 of a cylinder 178 which forms the main body of the tail stock mechanism. This lower portion 177 of the cylinder is provided with one or more longitudinally extending tapered slots or grooves, such as 179 and 180, at spaced points on that side thereof which is adjacent the work head, and tapered gibs or wedges 181 and 182 are inserted in the tapered grooves 179 and 180, respectively, to cooperate with the bore of the tail slide 52 and thereby clamp the lower portion 177 of the cylinder therein.

The tapered gibs or wedges are actuated by screws 183 and 184 which are threaded into the upper wall of a recess provided in the lower surface of the tail slide 52, these screws each being provided with an enlarged integral collar or washer 185, 186 which fits in a slotted opening in the side of the corresponding gib or wedge 181 and 182. Hence, when the said screws 183 and 184 are threaded inwardly, they carry the wedges or gibs upwardly, as viewed in Fig. 9, thus firmly gripping the portion 177 of the cylinder 178 and retaining the latter in proper position within the tail slide 52. A retainer 187 is provided in the tail slide 52, below the gibs or wedges 181, 182 to prevent the latter from dropping out of the slide if the screws 183 or 184 should be disengaged from their threaded bores. A suitable collar or washer 188 may be provided between a shoulder on the cylinder 178 and the top surface of the slide member 52, if desired, to provide a predetermined spacial relationship between the cylinder and the tool slide.

A piston rod 189 extends from the hollow interior of the cylinder 178 through an aligned bore in the lower portion 177. Adjacent its upper end, the piston rod is provided with a piston plate 190, which is illustrated as being integral with the piston rod and having a sliding fit within the interior of the cylinder 178. Piston packings 191 and 192 are provided upon the upper and lower surfaces of the piston plate, respectively, and retained thereon by rings 193 and 194, respectively, which are connected to the piston plate 190 by screws 195 and 196, respectively. There is thus provided a fluid-tight piston which moves downwardly within the cylinder when fluid under pressure is supplied through an opening 197 in the cover plate 198, exhaust being effected through an opening 199 in the lower side of the cylinder below the piston. The piston is moved upwardly within the cylinder when fluid pressure is supplied through the opening 199, the opening 197 then acting as the exhaust. A sealing means 200 is provided in the bottom of the cylinder 178 and cooperates with the piston rod 189 to prevent the leakage of fluid thereabout.

The lower end of the piston rod 189 is longitudinally bored for a considerable distance, and within this bore is inserted a tail center 201. The upper end of the tail center is recessed and

provided with a ball 202 for cooperation with a wear plate 203 provided at the inner end of the bore in the piston rod, the ball 202 and wear plate 203 permitting substantially frictionless rotation of the tail center relative to the piston rod. The tail center 201 is provided with an annular groove 204 with which the reduced diameter, inner end of a set screw 205 cooperates, the head of the screw being flush with or countersunk below the outer surface of the piston rod 189 so as not to interfere with the sliding of the latter within the bore of the cylindrical portion 177. The tail center 201 is also preferably provided with a helical lubricating groove 206 communicating with aligned lubricating openings in the slide 52 and the portion 177 of the tail stock, an oil cup 207 being screwed into these openings.

It will be apparent, from the construction just described, that when the piston is moved downwardly by the application of fluid pressure to the opening 197, the piston rod 189 moves the tail center 201 into engagement with the upper end of a workpiece clamped upon the chuck 162. The tail stock will remain in firm engagement with the workpiece throughout the machining operation by virtue of the fluid pressure acting upon the piston, rotation of the tail center with the workpiece being permitted by the rotatable mounting of the tail center in the hollow bore in the lower end of the piston rod. When the machining operation has been completed, the application of fluid pressure to the opening 199 and the use of the opening 197 as the exhaust, moves the piston and piston rod upwardly withdrawing the tail center 201 from engagement with the workpiece so that the latter may be removed, it being remembered that the work-gripping fingers 171 of the chuck are also released at this time.

The tail slide 52 for mounting the fluid pressure operated tail stock may be of substantially solid construction or may be formed as a relatively hollow member constructed similar to those illustrated in U. S. Patents Nos. 2,292,260 and 2,231,336. A mounting of the latter type is here disclosed to reveal how such tail slides may be modified to incorporate the illustrated tail stock mechanism. As shown in Fig. 8, the tail slide 52 comprises a casting in which are formed suitable ways for cooperation with the vertical ways 53 of the portion 54 of the work head D. The tail slide is further provided with a transversely extending bore 208 within one end of which is positioned a pinion 209 formed upon the inner end of a substantially cylindrical member 210. The member 210 has a central bore through which passes a bolt 211, the outer end of the latter being provided with a substantially cylindrical locking member 212. The locking member 212 has a tapered inner surface cooperating with a correspondingly tapered inner surface on a second cylindrical member 213 which is positioned within a bore 214 extending substantially transversely of the bore 208. A bolt 215, having a headed portion resting in a slotted opening in the vertical portion 54 of the work head D, extends outwardly through the cylindrical member 213 and is provided on its outer end with suitable nuts 216. The outer end of the bolt 211 is likewise provided with nuts 217. It will be seen, therefore, that when the nuts 216 and 217 are tightened, the members 212 and 213 will be locked in engagement and the bolt 215 will clamp these members, and hence the slide 52, to the vertical portion 54 of the work head. This clamping is further assisted by the previously described clamping means 55 which comprise suitable plates and screws cooperating with the vertical ways 53.

The interlocking of the members 212 and 213 position the pinion 209 for cooperation with a vertical rack 218 attached to the vertical portion 54 of the work head by suitable screws 219. By slightly loosening the nuts 216 and the clamping means 55 and by rotating the member 210, the pinion 209 thereon causes the tail slide 52 to move vertically with respect to the work head member by virtue of the cooperation between the pinion 209 and the teeth of the rack 218. When the tail slide has reached the desired position the clamping means may be re-tightened to retain the tail slide in its adjusted position.

In the tail slide mechanisms of the aforementioned patents there was no provision for vertical movement of the tail center relative to the tail slide, and hence a rack and pinion arrangement, similar to that just mentioned, for adjusting the tail slide was necessary to secure the proper engagement of the tail center with the work. Therefore, an operating handle was provided for the member 210. In the form of the tail stock, herein disclosed, it is no longer necessary to move the tail slide to effect engagement and release of each workpiece, since the tail center 201 is now moved vertically by fluid pressure to effect engagement with the work and subsequent release therefrom. Hence, the tail slide need only be adjusted once for each size of work and this adjustment need not be made with great exactitude. It follows that the rack 218 and the cooperating pinion mechanism are no longer necessary, since adjustment of the slide may be effected by simply loosening the clamping means and manually moving the tail slide upon the ways. Hence, when the tail slide mechanisms of the aforementioned patents are to be converted for use with the fluid operated tail stock herein disclosed, the reduced cylindrical portion 177 of the latter is simply inserted within the cylindrical opening provided in the tail slide 52 of the prior art type of tail center, and the operating handle for the rack and pinion mechanism is then replaced by a simple disk or cover plate such as 220, the rack 218 being omitted or left in place as desired since it no longer has any necessary function in the device.

In accordance with this invention, a novel mechanism is provided for moving each hob or tool head towards and away from the cooperating work head in timed relationship with the vertical movements of the latter, thereby causing "in-feed" of the hob or other tool to perform the desired hobbing or other machining operation and automatic return of the hob or other tool to its initial position after the desired operation has been completed. The mechanism for effecting this movement for each of the hob heads is the same and hence only one such mechanism will be described in detail.

As shown in Figs. 1, 2 and 11 through 16, the present preferred form of this mechanism includes a substantially channel-shaped member 221 which is secured to one side of the slidable member 43 of the tool head by means of bolts 222 and drive pins 223, a suitable spacer 224, or plurality of spacers, being interposed between the members 43 and 221 where necessary due to the shape of the former so that the web of the member 221 is rigidly held in substantially vertical plane. A member 225 is slidably supported

by the legs and the web of this channel member, the sliding member being prevented from displacement, other than sliding movement, by gibs 226 and 227, attached to the legs of the channel member and cooperating with horizontally extending recesses in the front face of the member 225 adjacent the upper and lower edges of the latter. The slide member 225 is also provided with a longitudinally extending bore 228, extending therein from the right-hand side thereof, as viewed in Fig. 12, and within this bore is positioned a sleeve nut 229 which is held from rotation and axial movement by drive pin 230 cooperating with a flattened side of the nut or passing through a secantly disposed slot or hole therein. Screwed into the sleeve nut 229 is one end of an adjusting screw 231 which is rotatably supported, adjacent its other end, by an end plate 232 secured to the forward end of the channel member, the screw 231 being held from longitudinal displacement by any suitable means.

In the construction shown, longitudinal displacement of the screw 231 is provided by an integral collar 233 provided upon the screw and cooperating with one side of the end plate 232. Forwardly of the collar, a non-threaded portion of the screw is journalled in the end plate, and adjacent the forward face of the end plate the screw is threaded and provided with a lock nut 234, the lock nut in turn having a set screw 235 to prevent loosening of the lock nut. The forward end of the adjusting screw 231 is provided with a polygonally shaped portion 236 to receive a wrench or other tool by which the adjusting screw may be turned to thereby adjust the position of the sliding member 225 relative to the channel member 221. The extent of this adjustment is indicated by a calibrated dial 237, which is secured to the screw between the polygonally shaped portion and the lock nut, the indicia on the dial cooperating with a mark or arrow upon the end plate 232.

One end of a link 238 is pivotally secured to the slide member 225 adjacent the inner end of the latter, the left-hand end as viewed in Figs. 12 and 14, by means of a stud bolt or the like 239. The other end of the link 238 is pivotally connected to the lower arm 240 of a bell crank lever, generally designated 241, by means of a stud or the like 242. This bell crank lever is pivoted intermediate its ends to a bracket 243, which is secured in a manner hereinafter described, to the annular member 40 of the turret B. The other arm 244 of the bell crank lever has its outer or upper end pivotally connected to the bifurcated lower portion of a threaded rod 245, the threaded portion of which is screwed into an adjusting sleeve 246, the bore of the latter being provided with oppositely directed threads in the upper and lower portions thereof. Threaded into the upper end of the adjusting sleeve 246 is the threaded lower end of a piston rod 247, the threads of which extend in the opposite direction to the threads on the rod 245. The upper end of the piston rod 247 is connected with a piston 248 slidable within a cylinder 249. This cylinder is pivotally mounted upon the cap member 58 of the turret B by means of a bracket 250 which has a depending ear 251 received between spaced, upwardly extending ears 252 and 253 attached to, or integral with, the upper end of the cylinder 249, a suitable pivot pin or the like 254 passing through aligned openings in the ears 251, 252 and 253. The cylinder 249 is adapted to have fluid pressure supplied thereto through an opening adjacent the bottom thereof by means of a pipe or conduit 255 so that the fluid under pressure thus admitted to the cylinder acts upon the piston 248 to urge the latter upwardly, any fluid above the piston being exhausted through a port not shown.

The construction thus far described is such that fluid pressure applied to the cylinder 249 through the pipe or conduit 255 acts upon the piston and through the piston rod 247 to rock the bell crank lever 241 in a counterclockwise direction, as viewed in Figs. 2 and 12. This rocking of the lever 241 tends to move the slide member 225 to the right, as viewed in Figs. 2 and 12, and since the slide member 225 is connected to the channel member 221 by the screw 231, and since the channel member is in turn connected with the sliding head member 43, this rocking movement of lever 241 tends to move the head member 43 of the hob head forwardly, that is to the right, as viewed in Fig. 2. Hence, the movable portion of the hob head is urged or biased in the direction of the work head thus tending to cause "in-feed" of the hobbing spindle and of the hob or other tool attached thereto. Movement of the tool or hob head in the direction just mentioned is, however, positively controlled by a cam carried by the cooperating work head D, as hereinafter described, so that "in-feed" of the hob or other tool is effected only in exact predetermined relationship with the vertical movement of the work head. The force with which the head member 43 is urged inwardly as just mentioned may be adjusted by adjusting the sleeve member 246, thereby varying the effective leverage of the bell crank lever 241, while the initial and final positions of the tool or hob head upon its ways 46, and hence the position of the tool relative to the work, may be adjusted by turning the adjusting screw 231.

The lower portion 48 of the work head D is provided with a bracket 256 into which is screwed the threaded lower end of a cam supporting shaft 257. The threaded upper end of shaft 257 is screwed into an enlarged boss 258 which is integral with, or attached to, a substantially vertical extending cam plate 259. The shaft 257 is provided with a polygonally shaped portion 260 intermediate its ends by which the shaft may be rotated and thereby adjust the elevation of the cam plate relative to the bracket 256, it being understood that the opposite ends of the shaft 257 are provided with oppositely directed threads. The threaded portions of the shaft 257 are provided with jam nuts 261 and 262 for cooperation with the bracket 256 and boss 258, respectively, to thereby lock the shaft 257 in its adjusted position.

The cam plate 259 is supported for vertically sliding movement by a plate-like member 263, the lower end of which is connected to a bracket 264 which is in turn connected to the adjacent vertical way 56 for the lower portion 48 of the work head D. As will be seen from Fig. 15, this plate-like member 263 is provided substantially centrally thereof with a substantially rectangularly shaped opening through which the boss 258 freely extends so that the shaft 257 is disposed on one side of the plate 263 while the cam plate 259 is disposed on the other side of the plate 263, the construction being such that the cam plate 259 extends closely adjacent the front face of the slide member 225 adjacent the

forward or right-hand end thereof as viewed in Figs. 2, 12 and 15. The cam plate 259 is provided with a suitable cam surface, which is here illustrated as comprising an elongated opening 265 with a forwardly extending recess or offset adjacent its lower end, and within this opening 265 is received a cam roller 266 rotatably mounted upon the slide member 225. The cam plate 259 is guided in its vertical movements by means of gibs 267 and 268, attached to rearwardly extending shoulders on the plate-like member 263 adjacent the longitudinal edges thereof, which gibs cooperate with suitable recesses in the cam plate 259 so as to form guideways for the latter, as is clearly shown in Fig. 16.

As mentioned above, the application of fluid pressure through the pipe or conduit 255 to the cylinder 249 exerts force upon the movable portion 43 of the tool or hob head C in a direction tending to move the latter, and hence the tool or hob spindle 41, toward the work spindle carried by the work head so that the cam roller 266 is held in positive engagement with the forward edge of the cam shaft 265. When the work head is in its lowermost position, however, the cam roller 266 upon the slide 255 will be positioned in the upper end of the cam slot or opening 265 in the cam plate 259 and hence the hob or tool head is prevented from moving forwardly under the action of the fluid pressure applied to the cylinder 249. As the work head D moves vertically upwardly the enlarged or recessed portion of the cam slot 265 will eventually come opposite the cam roller 266 and, since the roller is constantly urged against the forward edge of the cam slot 265, the hob head will then be moved forwardly, or to the right as viewed in Figs. 2, 12 and 15, under the force exerted by the pressure fluid in the cylinder 249. The cam slot recess is so designed that this movement of the tool head provides the desired amount of "in-feed." Additional vertical movement of the work head D occurs after this "in-feed" movement of the hob head, as will be seen from Fig. 15, during which additional vertical movement the hobbing of the workpiece is effected. It will be understood that the relative dimensions of the several portions of the cam slot 265 which are shown are simply illustrative of the one embodiment of the device and that these dimensions may be changed to effect greater or less vertical movement of the work head before the "in-feed" occurs and/or greater movement of the work head in its "in-fed" position.

Prior to the time that the lower end of the slot 265 engages the cam roller 266 the upward vertical feeding movement of the work head is discontinued by means hereinafter described and the work head is then returned to its initial position. During this return the cam plate 259 now moves downwardly so that the slot 265 forces the tool or hob head away from the work spindle, or to the left as viewed in Figs. 2 and 15, it being understood that this movement is in a direction opposite to that in which the tool or hob head is urged by the fluid pressure applied to the cylinder 249 so that the cam roller 266 is always in positive engagement with the cooperating cam surface in the slot 265 and hence the hob head is moved in either direction in exact predetermined relationship with the movement of the work head. The rearward movement of the tool or hob head acts through the mechanism connected between the latter and the piston 248 to move the latter against the fluid pressure applied to the cylinder 249.

During the normal operation of the machine, fluid pressure is continuously applied to the cylinder 249 so that the cam roller 266 is at all times in firm engagement with the forward edge of the cam slot 265. It is not necessary, however, that this biasing of the hob head in the direction of the work head be effected exactly as here illustrated and described. For example, a suitable spring may be substituted for the cylinder 249. Moreover, either a spring or fluid pressure operated device could be connected directly with the slide member 225 rather than through the disclosed lever system.

The fluid pressure for operating the clutch, the tail center and the chuck mechanisms and for exerting force to move the tool or hob head in the "in-feed" direction may be either hydraulic or pneumatic and may be supplied from any suitable source such as a reservoir and pump mounted in the base of the machine. As shown in the drawings, however, air pressure is utilized and is supplied to the machine from an outside source of supply such as the air line commonly provided in factories for cleaning purposes or the like. The air pressure is conducted from such a supply to the machine at the top thereof through a stationary pipe 269 (see Figs. 1 and 18). This pipe has a vertical extending portion 270 substantially in alignment with the vertical axis of the machine and the lower end thereof is journalled in a rotatable air distributing chest 271. This chest is supported above the motor 59 by a spider-like framework 272 having radially extending arms 273 connected with vertically extending frame members 274 which extend upwardly from the turret cap member 58 and are circumferentially spaced thereabout. Hence, the chest 271 rotates with the turret when the rotation motor 35 is energized. The air distributing chest 271 is provided with a plurality of radially extending pipes 275 for conducting the air pressure from the chest to each operational unit of the machine. Since all of the operational units of the machine are identical the air distribution from only one of the pipes 275 will be described.

The pipe 275 of each unit is connected to one end of a flexible conduit or hose 276 the other end of which is connected by a T 277 to the pipe or hose 278, and to a pipe or hose 279. The pipe or hose 278 is connected by a T 280 to the fluid pressure supply line 97 for the valve 96, which controls the operation of the clutch for the unit, and to the pipe or conduit 255 connected to the cylinder 249 of the "in-feed" mechanism. The pipe 279 is connected to a solenoid operated two-way valve 281, the solenoid 282 of which is energized by an electrical current flowing in a cable 283 extending to a suitable outlet 284 upon the cap member 58 of the machine's turret. From the valve 281 a pipe or hose 285 extends vertically downward adjacent the vertical portion of the work head D, the lower end of the pipe being connected with a T 286 from which a pipe or hose 287 extends to a pressure regulator 288. From the lower end of the pressure regulator, the previously mentioned pipe or hose 174 extends to the upper connection for the cylinder 172 of the fluid pressure operated chuck. A branch pipe or hose 289 extends from the T 286 to the upper opening 197 of the fluid pressure operated tail stock.

From the lower portion of valve 281, a pipe or hose 290 leads vertically downward adjacent the

portion 54 of the work head D, the lower end of this pipe or hose terminating in a T 291 to which is connected a pressure regulator 292 from which a branch pipe or hose 293 leads to the side exhaust opening 199 in the fluid operated tail stock. Also connected to the T 291 is one end of the previously mentioned pipe or hose 175, the other end of which is connected to the cylinder 172 for the fluid operated chuck.

The valve 281 is so constructed that when the solenoid 282 is deenergized the valve is positioned to cause fluid pressure from the pipe or hose 276 to communicate with the pipe 285, the pipe 290 being vented to the atmosphere through the valve. When the solenoid 282 is energized the valve 281 is operated to apply fluid pressure to the pipe 290, the pipe 285 then being vented to the atmosphere. It follows, therefore, that when the solenoid is deenergized the valve 281 causes fluid pressure to be supplied through the pipes 285, 287, and 174 to the cylinder 172 causing the rod 169 of the chuck 168 to actuate the latter for firmly engaging a workpiece. Fluid pressure is also supplied, through the pipe 289 causing the piston of the tail stock mechanism to be moved downwardly to engage the tail center 201 with the workpiece. Fluid pressure will be maintained in these lines throughout a cutting or hobbing operation, thus holding the parts in their aforementioned positions. When the cutting or hobbing operation is completed, the solenoid 282 is energized, as hereinafter described, actuating the valve 281 to vent the pipes 174, 287, 289 and 285 and to supply fluid pressure through the pipes 288, 175 and 293 thereby releasing the chuck and actuating the tail center 201 in a reverse direction to release the workpiece.

Since the chuck and tail center are held in work gripping positions by air pressure, a failure of the supply of air pressure to the pipe 269 would partially release the work with consequent damage thereto and to the hob or tool T if the latter is operating upon the work. Also, since the clutch is held in its disengaged position and the tool or hob head is continuously urged towards the work spindle by air pressure, a failure of the supply of these mechanisms would allow the clutch to improperly engage and would also cause improper operation of the "in-feed" mechanism. To prevent such conditions from occurring, the pipe 269 is provided with a pressure responsive electrical switch 294 (see Fig. 1). This switch is normally closed but if the air pressure drops below a predetermined value the switch opens thus stopping the entire machine as will become apparent from the subsequent description of the electrical circuit for the machine.

The machine is provided with a coolant system for supplying a cutting or cooling liquid to the hobs or tools during a machining or hobbing operation. The coolant or cutting liquid is supplied from a reservoir within the base of the machine by means of a pump, not shown, and by a conduit 295 and a pipe or pipes 296 to a trough reservoir which is not shown but which is located in the cap member 58 of the rotatable turrret. Equally spaced pipes 297, one for each unit, conduct the coolant or cutting liquid from the trough to valves 298, and to each of the latter is connected a pipe 299 (see Fig. 1). The lower end of each pipe 299 is provided with a nozzle 300 adjacent the hob or tool spindle 41 of the unit and so directed that the coolant or cutting fluid will flow over the hob or other tool and the work being cut thereby, the liquid being returned to the base of the machine by gravity for cleaning and further circulation. The valve 298, between the pipes 297 and 299 for each unit, is electrically operated and is controlled in a manner, hereinafter described, such that coolant is allowed to flow only when a cutting operation is being performed and is automatically terminated when the cutting operation has been completed. Lubrication for the machine is provided by a circulating system of conventional design, the vertical supply pipe 301 of which extends through the hollow turret (see Fig. 2).

Referring now to Fig. 20, it will be seen that the spindle supporting member 42 is provided with an outboard bearing support 302 and an inboard bearing support 303, the latter preferably being integral with the member 42. The bearing support 302 is provided with a non-rotatable sleeve bearing or bushing 304 and the bearing support 303 is provided with spaced antifriction bearings 305 and 306, the spindle 41 being journalled in the bearings for rotation and axial sliding by means of sleeves 307 and 308. The sleeve 307 both rotates and slides with the spindle 41 relative to the bushing 304 while the sleeve 308 rotates but is prevented from sliding relative to the bearings 305 and 306 by an integral shoulder 309 and by the mechanism connected thereto which is hereinafter described.

The spindle 41 has a shoulder 310 intermediate its ends for engaging one side face of a hob or other tool T, indicated by dot-dash lines in Fig. 20, the sleeve 307 engaging the other side face of the tool, with the tool and sleeve being held against longitudinal displacement relative to the spindle by means of a nut 311 provided upon the threaded outer end of the spindle 41. In the event the longitudinal extent of the tool T is less than the distance between the inner end of sleeve 307 and the shoulder 310, as is the situation illustrated in Fig. 20, one or more spacing collars or washers 312 may be employed as shown. A keyway 313 is provided in the spindle 41 by means of which the tool is keyed to the spindle to prevent relative rotation therebetween.

Attached to the spindle supporting member 42, and to the bearing support 303, is a housing 314 containing the mechanism for rotating and axially moving the tool or hob spindle 41. This mechanism includes a gear 315, disposed within the housing 314 and slidably keyed or otherwise attached for rotation with the spindle 41 and for relative axial movement therebetween. This gear, and hence the spindle, are driven by a gear 316 which is fixed upon the outer end of the shaft 117 for rotation with the bevel gear 116 (see Fig. 3) when the clutch 75 connects shaft 74 for rotation by shaft 68. The gear 315 has a cylindrical sleeve-like extension 317 extending through an opening in an inner wall 318 of the housing 314, and the spindle 41 has a threaded portion 319 of reduced diameter extending beyond the outer end of this sleeve extension 317 of the gear 315. Screws 320 extend through the sleeve extension 317 of gear 315 and are threaded into the flange or shoulder 309 of the sleeve 308 thus connecting these members for rotation together.

Screwed upon the inner end of the threaded portion 319 of the tool spindle 41 is a sleeve nut 321 the inner end of which is externally flanged. Between the flange of nut 321 and the adjacent end of the sleeve extension 317 of gear 315 is disposed a spacer 322. The sleeve nut 321 is provided with external threads on which is threaded one end of a sleeve 323, the outer end

of the latter being serrated. A pin 324 is inserted into the sleeve and sleeve nut, after the former has been screwed upon the latter, to prevent relative rotation between these parts when assembled. Within the sleeve 323 is disposed a sleeve nut 325 which threadably engages the threads on the portion 319 of the spindle, the outer end of this sleeve nut having a portion of reduced diameter forming an external shoulder which cooperates with an internal shoulder in the outer end of sleeve 323.

The sleeve nut 325 extends beyond the end of the sleeve 323 and has an annular member 326 keyed thereto, the inner face of the latter being serrated to cooperate with the serrations on the outer end of sleeve 323. The outer end portion of the nut 325 has a polygonally shaped axial opening 327 in which is disposed a correspondingly shaped inner end of a stud 328. This stud extends beyond the sleeve nut 325 and the annular member 326 and is preferably threaded intermediate its ends to receive a lock nut 329 which engages the outer face of the annular member. The stud is retained within the sleeve nut by means of a transversely extending drive pin 330 and the outer end 331 of the stud is polygonally shaped to receive a wrench or similar tool for a purpose hereinafter described.

A cap member 332 having an internal shoulder, in which is provided a spacer 333, is slipped over the inner end of the sleeve 323 and is connected to the sleeve extension 317 of gear 315 by one or more screws 334. The spacer 333 in the cap member 332 engages the flange on the sleeve nut 321 thus preventing axial displacement of the latter while permitting relative rotation therebetween. The threaded portion 319 of the tool spindle, the sleeve nut 325, and the sleeve 323 are rotatably supported by antifriction bearings 335 in a cover plate 336 removably mounted upon the outer end of the housing 314 by means of screws 337.

An annular gear supporting plate 338, having a central opening for rotatably receiving the cap member 332, is disposed within the housing 314 between the wall 318 and the cover plate 336. This gear supporting plate is fastened, as by means of one or more stud bolts 339, see Fig. 21, to the inner wall 318 in the housing, thereby securing the plate against rotation while permitting its easy removal. The lower portion of the plate 338 has an arcuate opening 340 therethrough within a portion of which is positioned a segmental plate member 341. The outer surfaces of this segmental plate are substantially coplanar with the outer surfaces of the plate 338 and has a width slightly less than the width of the opening 340 so as to have a sliding fit therein. The inner surface of the plate 338, adjacent the opposing 340 is recessed, as by milling or like operation, and fitted therein is a flanged portion 342 of the segmental plate 341. A compression spring 343 is disposed between one end of the arcuate opening 340 and the adjacent end of the segmental plate 341, and a bolt 344 is threaded into a threaded bore provided in the other end of the segmental plate.

A shaft 345 passes through the arcuate opening 340 adjacent the head of the bolt 344, the inner end of the shaft being journalled in a bore provided in the wall 318 of the housing 314. The outer end of this shaft is journalled in a boss 346 formed integrally with the cover plate 336 for the gear housing 314. Within the confines of the arcuate opening 340 the shaft 345 is provided with a cam 347, herein illustrated as a circular member having a flattened side. This cam engages the head of the bolt 344 and is keyed to the shaft 345 to rotate therewith. The outer end of the shaft 345 is provided with a suitable handle 348 for rocking the shaft and cam to bring the flattened face of the latter into engagement with the head of the bolt 344. When the cam is so positioned, the spring 343 moves the segmental plate 341 in a clockwise direction, as viewed in Fig. 21, for the purpose of disengaging the gearing for axially moving the hob spindle, which is about to be described. When the handle 348 is rocked to position the cam as shown in Fig. 21, the spring 343 is compressed and the gearing is engaged. A pair of projecting rods or studs 349 and 350 (see Fig. 11) are provided on the cover plate 336, one on each side of the handle, to limit the movement of the latter and define these two positions of the cam. Wear between the cam and bolt head are compensated for by adjusting the position of the bolt 344 within its threaded bore in the segmental plate 341.

To effect axial movement of the hob or tool spindle 41, an epicyclic gearing, preferably of the planetary type, is employed so that the axial movement of the hob or other tool may be effected by the same mechanism which rotates the tool, but at a very slow rate with respect thereto. This gearing comprises a sun gear 351 which is mounted upon a reduced diameter portion of cap member 332 and keyed or otherwise connected thereto for rotation therewith when the gear 315 is driven. The gear 351 is in mesh with a gear 352 which is one of a pair of planetary gears rotatably supported upon a short shaft or bolt 353, the latter being adjustably connected in a slot 354 in the gear supporting plate 338 to permit proper alignment of the gears. Integral with, or connected to, the gear 352 is a smaller gear 355 which meshes with a gear 356 rotatably supported upon a short shaft or bolt 357 connected in a slot 358 in plate 338. The gear 356 is also in mesh with a gear 359, which is the smaller of two integral gears, supported by means of a short shaft or bolt 360 in a slot 361 provided in the plate 338. The larger gear 362, which is integral with the gear 359, meshes with a gear 363 rotatably supported on a short shaft or bolt 364 which is adjustably mounted in a slot 365 provided in the plate 338. The gear 363 is the larger of an integral pair of gears, the smaller of which, designated 367, meshes with a gear 368 rotatably supported upon a shaft or bolt 369 mounted on the segmental plate 341. The gear 368 also meshes with a second sun gear 370 keyed to the sleeve 323 which, as previously mentioned, surrounds the sleeve nut 325 cooperating with the threaded portion 319 of the hob or tool spindle 41.

The construction just described is such that when the clutch 75 is engaged to provide rotation of the shaft 74, gear 116 and shaft 117, the gear 316 on the latter drives the gear 315 (see Figs. 3 and 20). Rotation of the gear 315 rotates the spindle 41 and consequently the hob or tool T is rotated in timed relationship with the rotation of the work spindle 47 and with the feeding movement of the latter, imparted by shaft 114, since all these elements are driven from the common shaft 74. When the hob or tool spindle 41 is rotated during the cutting or hobbing operation, the said spindle and the tool thereon are also axially moved at a very slow rate by operation of the planetary gearing mech-

anism just described. That is to say, rotation of the gear 315 rotates the gear 351, since the latter is keyed to the cap member 332 which is in turn connected to the gear 315, and the gear 351 in turn drives gears 352 and 355 (see Figs. 20 and 21). The latter gear drives gear 359 through the idler gear 356 with consequent rotation of the gear 362, since the latter is integral or connected to the gear 359. The gear 362 drives the integral gears 363 and 367, the latter driving the second sun gear 370 through the idler gear 368. Rotation of the gear 370 causes the sleeve 323 to rotate, since these members are keyed together. The serrations on the outer end of the sleeve 323 being held in engagement with the serrations on the annular member 326 by the nut 329, the annular member is also rotated with consequent rotation of the sleeve nut 325 which is keyed with the annular member. The sleeve nut 321 is also rotated since the sleeve 323 is connected thereto by the pin 324. This rotation of the sleeve nuts 321 and 325 causes the spindle 41 to be slowly advanced in an axial direction by virtue of the cooperation of the internal threads on the nuts with the threaded portion 319 of the spindle, the spindle sliding within sleeve 308 and the sleeve 307 sliding within the bearing 302.

The sleeve nut 321 is provided to take up any play between the sleeve nut 325 and the threaded portion 319 of the spindle. This is effected by loosening the lock nut 329 sufficiently to disengage the serrations on the annular member 326 from the serrations on the end of sleeve 323. A wrench or other tool is then applied to the outer end 331 of the stud 328 and the latter is rotated slightly thus rotating the nut 325 relative to the sleeve 323. The nut 321 remains stationary during this adjustment since it is connected with the sleeve 323 and hence the spindle is held stationary so that the nut 325 is rotated relative to the spindle sufficiently to take up the play therebetween. After this adjustment is effected the annular member is reenagged with the sleeve 323 and the lock nut 329 tightened thus reestablishing the driving relationship between the sleeve 323 and the sleeve nut 325.

The several gears in the planetary system may have any desired ratios but are preferably so chosen that the axial feed of the hob spindle is relatively slow. In the illustrated embodiment the rate is such as to produce complete axial movement during an interval of one work shift such as eight hours or the like. Hence, the hob or similar tool is so operated that the wear thereupon is substantially uniformly distributed over the entire surface of the hob. When the hob has been advanced its maximum amount in an axial direction, operation of that unit of the machine is automatically interrupted, after its working cycle is completed, in a manner hereinafter described, and the operator is advised thereof by the lighting of an electrical signal light L (see Figs. 1 and 25). This, however, does not interfere with the operation of the other units of the machine and hence the return of the hob to its initial position can be effected when it is convenient.

The hob spindle and hob are returned to their initial positions by first rotating the handle 348 to position the flattened portion of the cam 347 in engagement with the head of the bolt 344. The compression spring 343 will then move the segmental plate 341 within the opening 340 an amount sufficient to permit the gear 368 to be disengaged from the gear 367, the gear 368, however, remaining in continuous mesh with the gear 370. This disconnects the planetary gearing from the spindle advancing mechanism, and, by application of a wrench or similar tool to the polygonally shaped end portion 331 of stud 328 the latter may be rotated thus threading the portion 319 of spindle 41 through the nuts 321 and 325 and thereby returning the spindle and its hob to their initial positions, which will be evidenced by extinguishing of the signal light L. The hob or tool T is replaced and the wrench or other tool removed from the polygonally shaped portion 331 of stud 328. The handle 348 is then rotated in a reverse direction to again position the cam 347 with its rounded portion in engagement with the head of bolt 344, as shown in Fig. 21, thus reengaging the gear 368 with the gear 367, the alignment of the gears being maintained by the continuous meshing of the gear 368 with the gear 370 and by the cooperating arcuate shapes of the opening 340 and the sides of the segmental plate 341. The planetary gearing is thus reengaged to again slowly advance the hob when this unit of the machine is once more placed in operation. As previously mentioned, the rods or studs 349 and 350 upon the outer surface of the cover plate 336 limit the movement of the handle 348, thereby insuring proper positioning of the cam 347 in either of its two aforementioned positions.

Extending outwardly from the bearing support 303 of the hob shifting mechanism is a housing 371 for the electrical switch 372 which is actuated by the axial movement of the hob spindle to its extreme positions and controls operation of the spindle and of the previously mentioned signal light. Preferably, the switch 372 is of the type known as a "microswitch" having a double set of contacts, however, two separate "microswitches" each having a single set of contacts may be employed. The switch 372 is provided with an operating bar 373 extending substantially parallel with the outer surface of the bearing support 303 and cooperating with actuating pins 374 and 375 suitably mounted in bores extending through the bearing housing 303 adjacent the inner faces of the bearings 305 and 306, respectively. The tool or hob spindle 41 is provided with a transverse bore in which is disposed a two-piece pin 376, the two portions of which are separated by a compression spring 377. This spring urges the two portions of the pin outwardly of the bore in the spindle so as to extend through an axial slot 378 provided in the sleeve 308. The outer ends of this pin are positioned within a circular groove or recess on the inner face of a switch operating ring 379, the latter being slidably mounted on the outer surface of the sleeve 308 intermediate the bearings 305 and 306.

The construction is such that when the spindle 41 is at its starting or retracted position, as illustrated in Fig. 20, the switch operating ring 379 engages the actuating pin 375 thereby moving the switch operating bar 373 in a manner which operates the switch 372 to extinguish the signal light L and prepare the electrical circuit, hereinafter described, of that operational unit of the machine for a new operation. When the spindle 41 has been moved to its extreme advanced position, i. e., to the left as shown in Fig. 20, the switch operating ring 379 engages the actuating pin 374, causing the latter to move outwardly thereby moving the operating bar 373. This operates the switch 372 in a manner to light

the signal light L and open a portion of the electrical circuit for the corresponding hobbing unit of the machine to prevent the starting of the unit upon a new machining cycle until the spindle has been returned to its initial position, as above described.

The base 30 of the machine is provided with a vertically extending standard 380 and with a shield or cover 381 for the lower portion of the machine, the said standard being to one side of the loading station which is formed by reducing the height of a portion of the cover 381 (see Fig. 1). Adjacent the top of standard 380 is mounted a switch box 382 for controlling the rotation motor 35, the cut motor 59, and the motor for the coolant pump which is provided in the base of the machine and pumps coolant or cutting fluid through the conduit 295 and pipes 296 to the trough reservoir in the cap member 58. The switch box 382 is provided with a start button 383 and a stop button 384 for the rotation motor 35; start and stop buttons 385 and 386, respectively, for the cut motor 59; and start and stop buttons 387 and 388, respectively, for the motor of the coolant pump. The electrical interconnections of the switches operated by these buttons and their cooperating circuits are schematically represented in Fig. 25 together with a schematic representation of the electrical circuits for one unit of the hobbing machine.

The relays and circuits operated by the start and stop buttons 383 to 388, inclusive, are enclosed in a main control box 389 mounted upon the standard 380. This box is provided with a cover 390 and positioned within the box is a safety switch 391 which is adapted to interrupt the supply of electrical power to the machine when the cover is open, the switch being held in circuit closing position when the cover 390 is closed.

Electrical power is conducted to each of the rotating operational units of the machine by two separate sets of collector rings and brushes. As shown in Fig. 18, one of these sets comprises a pair of spaced collector rings 392, 393 mounted upon, but insulated from, a supporting ring member 394 which is bolted to the underside of the spider framework 272 supporting the air chest 271, and hence the collector rings are supported for rotation with the turret B. The collector rings are shielded by a cover which may be an integral part of the spider framework 272 or a separate member connected thereto. Cooperating with the collector rings 392 and 393, respectively, are brushes 395 and 396 which are stationarily supported by an arm or bracket 397 mouted upon the top of the cut motor 59. Wires, which are not shown in Fig. 18, conduct electrical power from the main control box 389 to the brushes 395 and 396 and other wires are connected to the collector rings at spaced points thereabout to conduct the electrical power to separate control cabinets or boxes 398 (see Figs. 1, 2 and 18) of which there is one for each operational unit of the machine.

The control cabinets or boxes 398 are mounted adjacent the top of the turret B upon the vertically extending frame members 274 and each box contains the relays and circuits for controlling the operation of the adjacent hobbing unit. Each cabinet 398 is provided with a cover 399 and positioned within each cabinet is a safety switch; the switches for the several cabinets being designated 399*a*, 399*b*, 399*c*, 399*d*, 399*e*, 399*f*, 399*g* and 399*h*, respectively, there being eight operational units in the illustrated machine each of which has a control cabinet 398. Each of these switches is adapted to interrupt the supply of electrical power to the machine when the corresponding cabinet cover 399 is open, power being restored only when all of the covers are closed.

The other set of collector rings and brushes, for conducting electrical power to the operational units of the machine, are mounted upon the cap member 58 of the turret. As shown in Figs. 2, 3 and 24, there are three spaced collector rings 400, 401 and 402 insulatedly mounted upon the upper surface of the cap member for rotation therewith. Cooperating with the collector rings 400, 401 and 402, respectively, are stationary brushes 403, 404 and 405 mounted in a housing formed by an annular flange 406 provided upon the lower end of the stationary housing 63. The brushes are accessible through an opening 407 in the flange 406 and this opening is normally closed by a cover plate, not shown. Mounted upon the flange 406 within the opening 407, and positioned to be operated by the cover therefor, is a safety switch 408 which is adapted to interrupt the supply of electrical power to the machine when the cover is open, the switch being held in circuit closing position when the cover is replaced. Hence, if a workman removes the cover for the purpose of inspection or replacement of the brushes he cannot come into contact with a "live" portion of the circuit. The brushes 403, 404 and 405 are connected with a power supply circuit in the main control box 389 and the collector rings 400, 401 and 402 are connected, at spaced points thereabout, to the circuits in the separate control cabinets 398 for each unit.

Depending from each cabinet 398 is a station or unit switch box 409 provided with the previously mentioned light L associated with the hobbing shifting mechanism, and with switch operators 410, 411 and 412 for controlling the coolant valve and the starting and stopping of the hobbing operation, respectively, for that unit. A toggle switch 413 is mounted at the bottom of the box 409 to selectively condition the unit for either manual or automatic operation as hereinafter described. As shown in Figs. 1 and 2, one side of each of the cabinets 398 is provided with a hobbing selector switch 414, an automatic return switch 415, a feed control switch 416 and an adjustable timer 417, each of which is manually settable for controlling the operation of the hobbing unit as hereinafter described. In addition, a switch 418, one for each unit, is mounted on the rear surface of one of the vertically extending frame members 274 for the corresponding unit (see Fig. 17). These latter switches are of the type which are spring urged to circuit opening position and each is provided with a rocking arm 419 on the outer end of which is positioned a roller 420 extending into the path of a single stationary cam 421. This cam is formed on or attached to the outer end of an elongated rod or bar 422, positioned adjacent the loading station for the machine and having its inner end supported upon the top of the machine between the motor support 60 and stationary housing member 63. Hence, as the turret of the machine rotates, the switches 418 are sequentially operated to closed position by the cam 421, the switches moving to open position as soon as the rollers thereof have passed the cam.

Referring now to Figs. 1, 2, 22 and 23 it will be seen that one side of the upper portion of the work head D, adjacent the ways 57, is provided with a plate 423 having spaced vertical slots 424

and 425. A longitudinally extending cam member 426 is adjustably mounted on the inner face of the plate by a bolt or bolts 427 passing through the slot 424, and a pair of spaced projections 428 and 429 are adjustably connected adjacent the top and bottom of the slot 425 by bolts 430 and 431, respectively. Adjacent the plate 423 of each work head the cap member 58 is provided with a switch 432 having a rocking actuating arm 433 extending into the path of the cam 426. A switch 434 is also mounted upon the cap member 58 adjacent the plate 423 and is provided with a rocking operating arm 435 extending into the path of the spaced projections 428 and 429 for operation thereby. The cap member 58 is further provided with electrical switches 436, one for each hobbing unit, each having an operating arm 437 extending into the path of spaced projections 438 and 439 which are adjustably connected to the other side of the top portion of the work head.

The switch operator 410 is a knob, movable between "on" and "off" positions for actuating the movable contact 410*a* (see Fig. 25) to and from circuit closing position, thereby controlling a solenoid CS which operates the coolant supply valve 298. Switch operator 411 is a push button, hereinafter referred to as the "start" button for the unit, adapted to actuate the movable contact 411*a* into engagement with the stationary contacts of the start switch, the contact 411*a* moving to open position when the button or operator 411 is released. The switch operator 412 is a push button, hereinafter referred to as the "stop" button for the unit, adapted to move the contact 412*a* from normally closed engagement with one set of stationary contacts and to simultaneously move the contact 412*b* into engagement with a second set of stationary contacts, the movable contacts 412*a* and 412*b* being returned to their initial positions upon release of the button 412. The toggle switch 413 comprises two movable contacts or blades 413*a* and 413*b* for movement to and from circuit closing position, marked "Auto" and "Man." in Fig. 25, the blades being maintained by the toggle mechanism in the position to which they have been actuated.

The switch 432 includes two spaced contacts 432*a* and 432*b*, the switch being adapted to move its upper contact 432*a* from a position in engagement with one set of stationary contacts and to simultaneously move its lower contact 432*b* into engagement with another set of stationary contacts when the switch operating arm 433 moves beyond the cam member 426, the contacts of the switch returning to their positions as shown in Fig. 25 when the arm 433 again engages and rides upon the cam member. The switch 434 likewise comprises two spaced movable contacts 434*a* and 434*b*, the switch being adapted to move its upper contact 434*a* from a position in engagement with one set of stationary contacts and to simultaneously move its lower contact 434*b* into engagement with a second set of stationary contacts when the arm 435 engages the projection 429. The movable contacts 434*a* and 434*b* remain in this new position until the arm 435 engages the projection 428 at which time the contacts are moved back to their initial position. The switches 436 for each of the work units are each provided with normally open contacts 436*a* and normally closed contacts 436*b*, the contacts 436*a* for all of the switches being connected in parallel and this parallel connection is in turn in series with a safety relay SR; the contacts 436*b* of this switch being connected in series with one of the main power supply lines for the control circuit of the corresponding unit. The switches 436 are spring urged to maintain their contacts in these positions, each switch being operated to close its contacts 436*a* and open its contacts 436*b* when the operating arm 437 strikes either the adjustable projection 438 or 439, mounted in slots upon the opposite side of the top of the hob head from the projections 428 and 429. The movable contacts of the switch 436 return to their original positions when the arm is moved out of engagement with either of the projections 438 or 439.

The hobbing selector switch 414 is movable between two positions corresponding to the two different methods of hobbing which may be performed by the machine, namely "normal" and "climb." This switch is provided with movable blades 414*a*, 414*b*, 414*c*, 414*d*, 414*e* and 414*f* which move together to change the circuit relationships thereby preparing the machine for operation in accordance with the selected mode of hobbing as hereinafter described. The automatic return switch 415 is provided with two movable contacts or blades 415*a* and 415*b*, operable together between "on" and "off" positions. The feed control or selector switch 416 is likewise provided with two contacts or blades 416*a* and 416*b*, operable together between "on" and "off" positions. The adjustable timer 417 comprises a conventional time relay TA having a movable contact TA–1 which is actuated at a predetermined time after the relay TA is energized, the length of this time interval being regulated by adjustment of the knob 417*a* of the timer.

As shown in Fig. 25, power is supplied to the hobbing machine from power supply lines 440, 441 and 442 provided with a circuit breaker 443. The power supply lines 453 and 455, on the machine side of the circuit breaker 443 are connected by wires 444 and 445 to the primary of a transformer 446, the secondary of which is connected with a circuit controlled by the previously mentioned start and stop buttons 383 and 388, inclusive, for controlling the operation of the rotation motor 35, the cut motor 59 and a motor 447 for the coolant pump. Thus, one lead 448 of the secondary of the transformer is connected through the normally open contacts PC–4 of a power controller PC, normally closed current overload switches 449, 450 and 451 to one side of the stop switch controlled by the button 384, the other side of this switch being connected to one side of the starting switch controlled by the button 383, the other side of the latter being connected with the rotation motor relay RT. The other side of the rotation motor relay RT is connected to a wire 452 leading to the other side of the secondary for the transformer 446. The relay RT is provided with four sets of normally open contacts RT–1, RT–2, RT–3 and RT–4. The contacts RT–1 are adapted to provide a holding circuit around the start button 383 when the relay is energized. The contacts RT–2, RT–3 and RT–4 are adapted to close an energizing circuit for the rotation motor 35 to the power lines 453, 454 and 455 which are respectively connected to normally open contacts PC–1, PC–2 and PC–3, these contacts in turn being connected with the circuit breaker 443.

The power controller relay PC, which operates the contacts PC–1, PC–2, PC–3 and PC–4, is connected in series with the secondary of the transformer 446 by the wire 452, brush 395, collector ring 392, unit control cabinet, normally closed switches 399*a* to 399*h*, normally closed contacts SR–1, switch 408, collector ring 393, brush 396 and normally closed contacts 391*a* and 294*a*,

the circuit being completed by a wire 456 connecting the latter contacts with the lead 443 for the transformer. The contacts 399*a* to 399*h* are the switches which are mounted within the control cabinets 398, while the SR–1 contacts are operated by the SR relay, the energization of the latter being controlled by the overtravel limit switches 436 mounted adjacent the upper end of each of the work heads. The switch 403 is that which is operated by the cover plate for the brushes 403, 404 and 405, and contacts 391*a* are those contained with the switch 391 which is operated by the cover 390 for the main control box 389. The contacts 294*a* are those which are contained within the pressure responsive switch 294 and are operated by the fluid pressure within the supply pipe 269. Consequently, the PC relay cannot be energized unless all of the cabinet covers have been secured in place, the cover placed over the collector ring brushes, fluid pressure of predetermined value is supplied to the machine, and each of the work heads of the latter is within its predetermined limits of travel. If all of these conditions be satisfied the PC relay is energized thus closing the contacts PC–1, PC–2, PC–3 and PC–4 supplying power to the machine. In the event any of the above mentioned conditions have not been fulfilled the PC relay will be deenergized thus opening its contact PC–1, PC–2, PC–3 and PC–4 interrupting all power to the machine except that supplied to the primary of the transformer 446.

Assuming that all of the conditions have been met and the PC relay has been energized, the rotation motor 35 is started by depressing the start button 383 thus energizing the relay RT, closing its contacts RT–1, RT–2, RT–3 and RT–4. In the event the rotation motor draws excessive current due to some abnormal condition, one or both of current overload relays 457, 458, provided in two of the power leads for the motor, operate to open the cntacts 449 thus deenergizing the RT relay and opening the circuit to the motor 35. During normal operation, however, the rotation motor, once energized, will remain in operation until the stop button 384 is actuated or the PC–1, PC–2, and PC–3 contacts are opened by an abnormal condition in the operation as previously mentioned.

Between the current overload switch 451 and the stop switch controlled by the button 384 is connected a wire 459 to which the stop switch controlled by the button 388, the start switch controlled by the button 397 and the relay P are connected in series, the circuit being completed by the wire 452. The relay P is provided with four sets of normally open contacts P–1, P–2, P–3 and P–4. The contacts P–1 provide a holding circuit around the start switch controlled by the button 387 while the contacts P–2, P–3 and P–4 are adapted to close the circuit from the power lines 453, 454 and 455 to the motor 447 for the coolant pump. Disposed within two of the leads to the coolant motor 447, between the latter and the contacts P–2, P–3, are a pair of current overload relays 460 and 461 which operate to open the current overload switch 450 in the event the motor 447 draws excessive current. It will be seen, therefore, that during normal operation of the machine, the pump for supplying coolant to the trough reservoir in the cap of the turret B is energized by operating the push button 387 and remains in operation until the stop button 388 is operated.

In parallel with the circuits for the RT and P relays is a circuit extending in series from the wire 459 through the stop switch controlled by the button 386, the start switch controlled by the button 385, and through the CT relay to the wire 452. The CT relay is provided with four normally open contacts CT–1, CT–2, CT–3 and CT–4 which are closed by energization of the CT relay when the start button 385 is actuated. The CT–1 contacts provide a holding circuit about the start button while the CT–2, CT–3 and CT–4 contacts close a circuit from the wires 453, 454 and 455 to the cut motor 59 for energizing the latter. Disposed within two of the leads for the cut motor are a pair of current overload relays 462 and 463 adapted to open the current overload switch 451 if the motor 59 should draw excessive current due to abnormal operation. During normal operation, however, the cut motor 59 remains in continuous operation, when once energized, until the stop button 386 is operated.

On the machine side of the PC–1, PC–2 and PC–3 contacts wires 464, 465 and 466 are connected with the power lines 453, 454 and 455. The other ends of these wires 464, 465 and 466 are, respectively, connected to the stationary brushes 403, 404 and 405 which, respectively, cooperate with the collector rings 400, 401 and 402 mounted within the housing 406 at the top of the cap member 58. A control circuit for each operational unit of the hobbing machine is connected to the collector rings by wires such as 467, 468 and 469. Only one of these control circuits is illustrated in detail in Fig. 25 since the others are identical and may be connected to the collector rings in parallel with the illustrated circuit by means of wires such as 470, 471 and 472. The connections of the switches associated with each operational unit of the machine and their mode of operation will be readily apparent from a consideration of Fig. 25, illustrating the circuit and switches for one of the units, in conjunction with the following detailed description of the operation thereof.

OPERATION

Conventional or "normal" hobbing.—Automatic operation

When all of the covers for the control cabinets or boxes and the cover for the housing of the collector brushes 403 to 405 are closed, air under pressure is applied to the pipe 269, and all of the work heads are at their lower positions within their predetermined limits of travel, the machine is prepared for conventional or "normal" hobbing by first closing the circuit breaker 443 thereby supplying current through the wires 444 and 445 to the transformer 446. This energizes the PC relay closing its contacts PC–1, PC–2, PC–3 and PC–4. The operator then presses the rotation start button 383 thus energizing the RT relay causing the contacts RT–1, RT–2, RT–3 and RT–4 to close. Contacts RT–1 provide a holding circuit about the start button 383 so that the latter may now be released without deenergizing the relay RT. The contacts RT–2, RT–3 and RT–4 supply three phase electrical power from the power lines 453, 454 and 455 to the rotation motor 35 energizing the latter thus driving the worm 37 and worm wheel 38 causing the turret B to rotate.

The operator next presses the cut motor start button 385 thus energizing the relay CT which closes its contacts CT–1, CT–2, CT–3 and CT–4. The contacts CT–1 provide a holding circuit for the relay CT maintaining the latter energized

after the start button 385 is released. The contacts CT–2, CT–3 and CT–4 supply three phase electrical power from the power lines 453, 454 and 455 to the cut motor 59 energizing the latter and thus driving the flexible drive 62, sleeve 64 and bevel gear 66. The bevel gear 66 in turn drives the bevel gears 67 rotating the driving member 76 of the clutch 75 of each unit. These clutches are held in their disengaged positions since the clutch solenoids 101 are energized, as hereinafter described, by the closing of the contacts PC–1, PC–2 and PC–3, thus actuating the valves 96 to supply air pressure to the cylinders 91 thereby moving the driven member 77 of each clutch out of engagement with its driving member.

The operator also presses the start button 387 thus energizing the relay P thereby causing the contacts P–1, P–2, P–3 and P–4 to close. Contacts P–1 provide a holding circuit for the relay P maintaining the latter energized after the start button 387 is released. The contacts P–2, P–3 and P–4 connect the motor 447 for the coolant pump to the three phase power lines 453, 454 and 455. Cutting fluid or coolant is, therefore, pumped from the reservoir in the base of the machine to the trough reservoir in the turret cap member 58. The coolant cannot, however, flow through the nozzle 300 at this time since the valves 298 are closed.

The circuits thus established are normally not disturbed during the operation of the machine but in the event that any of the motors 35, 59 or 447 draw excessive current the operation of all three motors is terminated. Thus, excessive current flow to the motor 35 causes the relay 457 or relay 458 to open the current overload contacts 449; excessive current flow to the motor 447 causes the relay 460 or relay 461 to open the current overload contacts 450; and excessive current flow to the motor 59 causes the relay 462 or relay 463 to open overload contacts 451. Also, opening of any of the covers of the control boxes, opening of the cover for the brushes 403 to 405, failure of the air supply, or over travel of any of the work heads of the machine deenergizes the PC relay thereby stopping the entire machine including the motors 35, 59 and 447. In addition, each of these motors 35, 59 and 447 may be individually stopped, if desired, by operating the corresponding stop buttons 384, 386 or 388.

As the turret rotates, the hobbing units successively pass the loading station adjacent the vertical standard 380. As each unit approaches this station the operator sets the hobbing selector switch 414 on the unit control cabinet 398 for "normal" or conventional hobbing, the automatic return switch 415 to the "off" position, and the feed control switch 416 to the "off" position. He also moves the toggle switch 413 to its "Auto." (automatic) position, and turns the coolant control knob 410 to its "on" position.

The previously mentioned closing of the contacts PC–1, PC–2 and PC–3 has supplied electrical current through the wires 464, 465 and 466 to the brushes 403, 404 and 405, and thence to the collector rings 400, 401 and 402 to which are connected the power supply lines 467, 468 and 469 for the unit. Hence, current is supplied through the wires 467 and 469 to the primary of a transformer 473. The secondary of this transformer is connected through fuses 474 and 475 to wires 476 and 477. Current is thus supplied through wire 476 and the normally closed contacts CL–1, of relay CL, to the solenoid 101 for the clutch valve 96, the circuit being completed through a wire 478 connected to the wire 477. Therefore, the valve 96 has been operated to supply air pressure for effecting disengagement of the clutch as previously described. The circuit to the solenoid 282, for the valve 281 controlling the chuck and tail stock, is open at the normally open contacts AS–1 and AS–2, of a relay AS, and hence the solenoid 282 is deenergized. Therefore, the valve 281 is positioned to supply air pressure for holding the chuck and tail center in their closed or work-engaging positions.

As the unit approaches the loading station, the operator momentarily depresses the stop button 412. This opens the circuit through the contact 412*a* and closes a circuit through the contact 412*b*. This circuit extends from the wire 476 through the normally closed contacts 436*b* of the overtravel limit switch 436 for the unit, current overload contacts 479, wire 480, the lower contact 412*b* of the stop switch, wire 481, wire 482, wire 483 and through the coil of a relay DR to the wire 478. Hence, the DR relay is energized closing its normally open contacts DR–1, DR–2 and DR–3. Closing of the contacts DR–1 provides a holding circuit for the DR relay about the stop switch so that the relay remains energized when the stop button 412 is released opening the circuit through its lower contact 412*b*.

The initial positioning of the toggle switch 413 to its "Auto." position and the automatic return switch 415 to its "off" position now provides a circuit from wire 480 through the now closed contacts DR–1, contact 413*b* of switch 413, contact 415*a* of switch 415, normally closed contacts FR–4 and FC–3 of relays FR and FC, and through the now closed contacts DR–3 and the coil of relay AS to the wire 478. Hence, the relay AS is energized closing its contacts AS–1 and AS–2 and thereby supplying current from wires 467 and 469 to the solenoid 282 for the valve 281. The latter is, therefore, operated to supply air pressure to the tail stock and chuck mechanisms in a direction to open or disengage the chuck and retract the tail center. The operator then inserts a workpiece between the chuck and tail center and depresses the start button 411.

Actuation of the start button 411 causes its contact 411*a* to close a circuit extending from wire 476 through the normally closed contacts 436*b* of the overtravel limit switch 436, the normally closed contacts 479 of a current limit switch, the upper contact 412*a* of stop switch 412 to a wire 484 and from the latter through a wire 485, contact 411*a*, wire 486, contact 414*a* of the hobbing selector switch 414, contact 434*a* of switch 434, contact 414*c* of the hobbing selector switch 414, wire 487, and through the coil of the relay FR to the wire 478. This energizes relay FR closing its normally open contacts FR–1 and FR–2 providing a holding circuit for the relay about the start button 411 so that the relay FR remains energized when the button is released. The contacts FR–3 are also closed for a reason to be explained hereinafter. The contacts FR–4 of the relay are opened thus deenergizing the relay AS causing the latter to open its contacts AS–1 and AS–2 and thereby deenergize the solenoid 282. This deenergization of solenoid 282 allows the valve 281 to move to a position which supplies air under pressure to the chuck and tail stock mechanisms in a manner to cause the chuck to grip the work and the tail center to move into

engagement with the upper end of the workpiece. The energization of the relay FR also has effected opening of the normally closed contacts FR–5 for a purpose hereinafter described.

As the turret continues to rotate, the hobbing unit which has just been provided with a workpiece, carries its rotation controlled switch 418 on the back of the vertical support 274 past the stationary cam 421 and the latter engages the roller 420 of the switch momentarily moving its normally open contacts 418*a* to closed position. This closes a circuit from the wire 484 through the previously closed contacts FR–1, wire 488 and the now closed contacts DR–2 and 418*a*, wire 489 and through the coil of a relay ER to the wire 478. This energizes the relay ER causing it to close its normally open contacts ER–1, ER–2 and ER–3 and to open its normally closed contacts ER–4. The contacts ER–1 provide a holding circuit about the contacts 418*a* of switch 418 maintaining the relay ER energized after the turret has moved the switch 418 past the cam 421. Closing of the contacts ER–2 closes a circuit from the wire 484 through the normally closed contacts 372*a* of the hob shift actuated switch 372, the now closed contacts ER–2, wire 493, the normally closed contact TA–1 of the time delay mechanism and the upper contact 432*a* of the switch 432, to and through the coil of the RU relay circuit to the wire 478. This energizes the RU relay causing the latter to close its normally open contacts RU–1, RU–2, and RU–3. The closing of these contacts supplies current from the wires 467, 468 and 469 through the wires 491, 492 and 493, the now closed contacts RU–1, RU–2 and RU–3, and the hobbing selector contacts 414*e*, 414*f*, to the rapid traverse motor 160 for the unit. Interposed in the wires 491 and 492 are current overload relays 494 and 495 which are adapted to open the current overload contacts 478 if the motor 160 should draw excessive current.

The rapid traverse motor 160, which is a reversible three-phase motor, is therefore energized in a direction to move the work head vertically upward through the action of the worm 163, worm wheel 164 and feed shaft 155, the worm shaft 162 being freed for rotation by the supplying of current from the wires 491, 493 through the normally closed contacts BR–1, BR–2 to the electrically operated brake 167 which is thus released. Since the clutch 75 is held in its disengaged position at this time, the feed nut 154 will remain stationary due to the locking action of the worm wheel 153 and the worm 152 so that the rotation of the feed shaft 155 causes the work head D to move vertically upward at a relatively rapid rate. This movement of the work head continues until the arm 433 of the switch 432 moves off of the cam 426, the latter being adjusted so that this action occurs when the upper portion of that part of the workpiece which is to be hobbed is adjacent the hob. Throughout this rapid movement of the work head, the tool or hob head C remains stationary upon its ways 46 since, although the fluid pressure which is continuously supplied to the cylinder 249 biases or urges the tool head towards the work head, the interengagement of the cam roller 266, carried by the tool head, in the narrow portion of the cam surface or slot 265 carried by the work head prevents the tool head from "in-feeding" at this time. This narrow upper portion of the cam surface or slot 265 has sufficient length and the cam 426 is so adjusted that the relatively rapid movement of the work head is terminated when the roller 266 is just leaving that portion of the slot 265.

The closing of the ER–2 and ER–3 contacts closes a circuit from the wire 484 through the contacts 372*a*, ER–2, ER–3, wire 496, wire 497, the normally closed contacts CL–2 and the coil of a relay TR to the wire 478. The TR relay is of the time delay type adapted to open its contact TR–1 a few seconds after the relay is energized. Consequently, a short time after the TR relay is energized the contact TR–1 is opened deenergizing the FC relay, which was initially energized by the closing of the ER–3 contacts through a circuit extending from wire 490 through the ER–3 contacts, wire 496 and the TR–1 contact. The TR–1 contact is held open maintaining the FC relay deenergized until the CL relay is energized as hereinafter described. This movement of the arm 433 moves the contacts 432*a* and 432*b* from their positions as shown in Fig. 25 to bring the contact 432*b* into circuit closing relationship and to open the circuit through the contact 432*a*. This deenergizes the relay RU thereby opening the contacts RU–1, RU–2 and RU–3 so that the rapid traverse motor 160 and the solenoid for the brake 167 are deenergized. Consequently, the brake is applied to the worm shaft 162 preventing any residual rotation thereof and thus terminating the relative rapid movement of the work head simultaneously with the deenergization of the motor 160.

The contact 432B of the switch 432 now closes a circuit from the wire 490 through the contact 418*a* of the coolant switch, which was initially positioned to its closed or "on" position, and through the solenoid CS to the wire 478 and the energization of the solenoid CS effects opening of the coolant valve 298. A circuit is also completed from the wire 490 through the contact 432*b* and a wire 498 to and through the coil of the relay CL to the wire 478. Energization of the CL relay opens its normally closed contacts CL–1 and CL–2 and closes its normally open contacts CL–3. Opening of the contacts CL–1 deenergizes the solenoid 101 whereby actuating the valve 96 in a manner to terminate the supply of air under pressure to the clutch operating cylinder 91 and also establishing communication with the cylinder through the valve to the exhaust port 98. Consequently, the springs 80 of the clutch 75 now act to engage the driving and driven members thereof, this action being retarded, however, by the fact that the exhaust of air from the cylinder 91 is regulated by the adjustable orifice controlled by the screw 99. Hence, the members of the clutch are engaged at a suitable rate to prevent grabbing. The cut motor 59 now drives the shaft 114 through the gears 66, 67, shaft 68, clutch 75, shaft 74 and the gears 103 and 113. Also the shaft 117 is rotated by the gear 116 which meshes with gear 107 splined to the shaft 74.

The rotation of the shaft 114, acting through the gearing mechanism contained in the lower portion 48 of the work head D, rotates the worm 141 and worm wheel 142 thereby rotating the work spindle 47 and the workpiece supported thereon by the chuck 168 and tail center 291. In addition, the rotation of the shaft 114, acting through the gearing in the lower portion of the work head D, rotates the worm 152 and worm wheel 153 thus causing the nut 154 to rotate about the feed screw 155 which is now held from rotation by the engagement of the brake 167 with

the worm shaft 162. The rotation of the nut 154 therefore causes the work head to move vertically at a relatively slow feeding rate carrying the workpiece in cutting engagement with the hob which is now rotating, the hob being driven by the shaft 117 through the gears 316 and 315, it being understood that the initial part of the work head movement at the feeding rate brings the recessed portion of the cam slot 265 opposite the cam roller 266 so that the hob or other tool is moved into engagement with the workpiece under the force of the fluid pressure in cylinder 249. The width of the recess in the cam slot and the adjustment of the "in-feed" mechanism are such that the hob or other tool engages the workpiece for the desired depth of cut. Consequently, the workpiece is hobbed as it is moved past the hob at the relatively slow feeding rate. In addition to its rotation and "in-feed," the hob is also axially moved at a very slow rate by operation of the planetary gearing connected therewith and during the hobbing operation, coolant is supplied to the hog and workpiece through the nozzle 300 since the valve 298 has been opened by the previously mentioned energization of the CS solenoid which controls this valve.

The opening of the CL–2 contacts by the energization of the CL relay deenergizes the TR relay causing the TR–1 contact to close the circuit through the relay FC thus energizing the latter. The energization of the FC relay causes it to close its normally open contacts FC–1 and open its normally closed contacts FC–2 and FC–3. The vertical feeding movement and the rotation of the workpiece together with the rotation of the hob now continue until the work head has moved upwardly the predetermined distance sufficient to complete the hobbing operation on the workpiece, the projection 429 being set to engage the arm 435 of switch 434 when this distance has been traversed and which distance is less than the length of the recessed portion of the cam slot so that the arm 435 is actuated before the cam roller 266 engages the bottom of the cam slot. The engagement of arm 435 with the projection 429 moves the contacts of the switch 434 from the position shown in Fig. 25 to bring the lower contact 434*b* thereof into circuit closing position and to open the circuit through the upper contact 434*a*. This breaks the circuit for the relay FR deenergizing the latter thus opening its contacts FR–1 and FR–2 in the holding circuit, opening its contacts FR–3, closing its contacts FR–4 in the circuit of relay AS, and closing its contacts FR–5.

Opening of the contacts FR–1 deenergizes the relay FR and also deenergizes the relay ER causing the latter to open its contacts ER–1, ER–2, ER–3 and close its contacts ER–4. Opening of the contacts ER–1 removes the bridging circuit about the contacts DR–2 and 418*a*, while opening of the contacts ER–2 opens the circuit to the solenoid CS for the coolant valve 298 and the circuit for the CL relay. The deenergization of the CS solenoid causes the valve 298 to close terminating the supply of coolant to the work and hob while deenergization of the CL relay closes the contacts CL–1 and CL–2. Closing of the contacts CL–1 reenergizes the solenoid 191 operating the valve 96 to supply air under pressure to the cylinder 91 thus disengaging the clutch 75 so that the feeding movement of the work and the rotation thereof and of the hob are terminated. The workpiece is not immediately released, however, since the circuit to the AS relay is now open at the FC–3 contacts due to the continued energization of the FC relay under control of the contract TR–1 of the time relay TR. The deenergization of the CL relay, however, again closed the CL–2 contacts, thus reenergizing the TR relay which operates a few seconds later to open its TR–1 contact thus denergizing the FC relay.

The deenergization of the FC relay opens its contacts FC–1, closes its contacts FC–2 and its contacts FC–3. Closing of the contacts FC–3 now provides a circuit therethrough and through the DR–3 contacts, which remain closed under the continued energization of the DR relay, for energizing the AS relay. This causes the AS–1 and AS–2 contacts to close thereby energizing the solenoid 282 which in turn operates the valve 281 to supply air pressure to the chuck and tail stock mechanisms in a direction to cause the chuck to be released and the tail center to move from engagement with the workpiece thus releasing the latter. This time delay of the release of the workpiece, due to the TR relay, is provided to insure that the clutch has entirely disengaged prior to the release of the workpiece.

The operation of the machine is so timed that each hopping unit is sequentially returned to the starting or loading station by the time the hobbing operation of that unit is completed and its chuck and tail center are released. As each unit reaches the starting or loading station, the operator removes the work and again presses the start button 411 moving the contact 411*a* into circuit closing position. A circuit is therefore closed from the wire 484 through the contact 411*a*, a wire 499, wire 500, movable contact 414*b* of the hobbing selector switch 414, the contact 434*b* of the switch 434 which is now in its lower or circuit closing position, contact 414*d* of the hobbing selector switch 414, the normally closed contacts FC–2 and through the coil of a relay DN to the wire 478 thus energizing the relay DN. The FC–2 contacts are provided to prevent energization of the DN relay until after the TR relay has operated to open its TR–1 contact and thus deenergize the relay FC, thereby providing a time delay to insure complete disengagement of the clutch 75 prior to energization of the rapid traverse motor 160 for moving the work head back to its initial position.

The energization of the DN relay closes its normally open contacts DN–1, DN–3, DN–4 and DN–5 and opens its normally closed contacts DN–2. The contacts DN–1 provides a holding circuit for the relay DN about the start switch so that when a button 411 thereof is released the relay remains energized. Closing the contacts DN–3, DN–4 and DN–5 supplies current to the motor 160 in a direction to cause the latter to rotate in the opposite direction from that in which it rotated when energized through the RU–1, RU–2 and RU–3 contacts. This is effected by so connecting contacts DN–3 and DN–4 that they reverse the motor leads 491 and 492. The current supplied by the leads 491 and 492 also flows as before through the normally closed contacts BR–1, BR–2 energizing the solenoid of the brake 167 thus releasing the latter. Hence, the rapid traverse motor 160 rotates and drives the worm 163 and worm wheel 164 in the reverse direction to that in which they were actuated during the upward rapid traverse of the work head. Consequently, the work head is now moved downwardly at a rapid rate and during this downward movement, the cam 426 engages the

arm 433 effecting resetting of the switch 432 to the position illustrated in Fig. 25. As the work head moves downwardly the cam plate 259, being carried therewith, forces the roller 266, and hence the hob head, back to the initial position in which the roller 266 is in the narrow upper portion of the cam slot and the hob is removed from its forward, operating position.

When the work head D has reached its lower position the projection 429 engages the arm 435 moving the contacts of the switch 434 back to their initial positions as illustrated in Fig. 25 thus opening the circuit through the contact 434b. This breaks the circuit for the relay DN deenergizing the latter and opening its contacts DN–1, DN–3, DN–4 and DN–5 and closing its contacts DN–2. Opening the contacts DN–1 breaks the holding circuit for the DN relay while opening of the contacts DN–3, DN–4 and DN–5 deenergizes the rapid traverse motor 160 and the solenoid for the brake 167 so that the motor is stopped and the brake applied thus terminating movement of the work head which occurs before the roller 266 strikes the top of the cam slot 265. The closing of the DN–2 relay does not perform any function at this time but is employed for a purpose hereinafter described.

This rapid traverse back to the initial position is completed while the work head unit is still passing the loading station and the cycle may be repeated by inserting a new workpiece and momentarily depressing the start button 411. This will again close the circuit through the contacts 434a of the switch 434 to energize the FR relay, the circuit operating as before described and therefore the description thereof need not be repeated except to note that the energization of the FR relay opens its contacts FR–4 thus deenergizing relays AS, opening the contacts AS–1, AS–2 of the latter. This deenergizes the solenoid 282 for the valve 281, thus again allowing air pressure to operate the chuck and tail stock mechanisms to grip the new workpiece, the chuck and tail stock mechanisms having been held in their open positions during the rapid traverse downwardly of the work head. This operation of inserting and removing workpieces and momentarily depressing the start button is performed for each work head as it moves past the loading station. Hence, the operator has simply to press a single button for each unit and to load and unload the work, during the normal operation of the machine, the initial actuation of the stop button being necessary only when the unit is first placed in operation, since the DR relay, when once energized by operation of the stop button, remains energized throughout subsequent operations.

In the event it is desired to stop a unit during its operation, the stop button 412 is momentarily depressed thus opening the circuit through the contact 412a thereby deenergizing all of the relays and solenoids for the unit except the AS relay and the clutch solenoid 101 which control the work gripping means and the clutch respectively. Consequently, when the stop switch is actuated during an operation of the unit, air pressure is supplied to the cylinder 91 and to the cylinders for the chuck and tail stock mechanisms to hold the clutch 75 disengaged and to release the chuck and tail stock. Since the DN and RU relays will also be deenergized, all movement of the work head is terminated and the workpiece is released.

In the event the work head travels either above or below its predetermined limits the corresponding projection 438 or 439, respectively, will operate the arm 437 of the switch 436 moving the contact 436a of the latter to close the circuit therethrough which is in series with the SR relay. The SR relay is thus energized and opens its SR–1 contacts which are in series with the power controller relay PC. The PC relay is therefore deenergized openings its contacts PC–1, PC–2, PC–3 and PC–4 which consequently remove all power from the machine thereby terminating the operation of all units and also of the rotation motor 35, cut motor 59 and coolant pump motor 447. The contacts 436a for all of the overtravel limits switches 436 are connected in parallel so that if any one of the work heads travels above or below its predetermined limits the SR relay is energized as above described. There is preferably only one SR relay for all the units of the machine, the control circuits for the other units being connected to extensions of the wires 476 and 477. The switch 436 of each unit is also provided with a set of normally closed contacts 436b in series with the main energization circuit for the relays and switches of each unit so that operation of the switch 436 opens the circuits through these contacts 436b as an additional safety precaution. Also, as previously mentioned, the supply leads 491 and 492 for the rapid traverse motor 160 are provided with current overload relays 494 and 495 which operate to open the contacts 479 in the current supply path for the relays of the unit in the event the motor 160 draws excessive current.

During the normal operation of the hobbing machine the hob of each unit is slowly advanced in an axial direction by the mechanism illustrated in Figs. 8 and 9 to uniformly distribute the wear on the hob along its entire length. When the hob has reached its extreme forward position, corresponding to the time when it should be replaced or reground, the switch operating ring 379 engages the actuating pin 374 closing the contacts 372b of the switch 372 and opening the contacts 372a thereof. Closing of the contacts 372b will close a circuit from the wire 434 through the normally closed contacts ER–4 and the light L of the unit to the wire 478 thus lighting the light and indicating that the hob has reached its extreme position. However, the ER–4 contacts are held open except when the work head is moved downwardly after the hobbing operation has been completed or when the work head is in its starting position. Therefore, the light is not energized if the work head be moving upward in rapid traverse or is effecting hobbing but is energized only when the work head is moving vertically downward or is at its starting position.

Opening of the contacts 372a prevents energization of the RU, FC and CL relays. This means that if a new cycle is attempted to be started, after the hob has shifted its entire length and lighted the light L, the cycle cannot actually begin since the rapid traverse motor will not be energized. However, if the hob be in the process of cutting or hobbing, when it has reached its predetermined limit and opened the contacts 372a, the hob will continue to perform its complete operation upon the workpiece because the FC–1 contacts are now closed and provide a holding circuit for the CL relay through the ER–3 contacts. This results from the fact that the energization of the ER relay at the beginning of the cycle has closed the ER–2 and ER–3 contacts and the subsequent energization of the CL relay has

opened the CL–2 contacts. Hence, the TR relay is deenergized so that the contact TR–1 is in circuit closing position and the FC relay has therefore been energized through the closed contacts ER–2 and ER–3. The energization of the FC relay closes its FC–1 contacts providing a holding circuit therefor and also providing a circuit for continuing energization of the CL relay. It follows therefore that the contacts 372*a* of the switch 372 will prevent the beginning of a new work cycle of the hob unit but will not interfere with the completion of a work cycle already begun.

This action of the switch 372, in preventing the start of a new cycle for a hobbing unit when the hob thereof has moved to its extreme advance position, does not interfere with the operation of the other units of the machine. The unit thus placed out of operation may be restored to operating relationship by returning the spindle 41 to its extreme retracted position. This is effected by disengaging the planetary gearing through operation of the handle 348 and rotating the stud 328 by a wrench or other tool placed upon the polygonally shaped end 331 thereof. When the spindle has thus been returned to its initial position, the ring 379 thereon engages the pin 375 thus operating the switch 372 to close its contacts 372*a* and open its contacts 372*b*, this being indicated by the extinguishing of the light L. The unit may then be again placed in operation by actuating the start button 411.

The contacts FR–3 are provided in parallel across the contacts DR–1 to enable the operation of the unit to be picked up after a current failure by actuating the start button 411. These contacts are necessary since a current failure will have deenergized the relay DR, opening its holding contact DR–1. In order that the unit may be started by simply actuating the start button 411, it is necessary that a means be provided for again energizing the DR relay by this actuation of the start button. In the circuit shown this is possible because actuation of the start button energizes the FR relay thus closing the contacts FR–3 and thereby providing an energizing circuit for the relay DR, the energization of which again closes the contacts DR–1 re-establishing the holding circuit for the DR relay.

Conventional or "normal" hobbing with "clean-up."—Automatic operation

In certain instances it is desirable to maintain the workpiece and hob in rotation but without feeding of the workpiece at the end of the hobbing or cutting operation to provide for "clean-up." This is readily effected in the machine by setting the feed control switch 416 to the "on" position, the setting of the other switches remaining the same as previously described. This setting of the control switch moves the contacts 416*a* and 416*b* into circuit closing relationship. The hobbing unit is then placed in operation and functions as above described until the work head has reached its uppermost position where the projection 429 engages the arm 435 of the switch 434 moving the latter to place its lower movable contact 434*b* in circuit closing position. While the ER relay is deenergized by this operation of the switch 434, the clutch 75 is not now disengaged as before since a holding circuit therefor has been provided through the FC–1 contacts, wire 496, contacts CL–3, contact 416*b* of the feed control switch 416, wire 498, contact TA–1, contact 432*b* of the switch 432 which has been moved into circuit closing condition by the movement of the work head, and through the wire 498 to and through the CL relay to the wire 478. Likewise, the CS solenoid for operating the coolant valve 298 also remains energized, it being remembered that the contact 410*a* has been placed in the "on" position by operation of the control knob 410. Therefore, when the work head has reached the upper position, moving the switch 434 to open the circuit through contact 434*a*, the CL relay remains energized.

The opening of the circuit through the contact 434*a*, however, deenergizes the relay FR thus closing its contacts FR–5 and this provides a circuit from the wire 484 through the now closed contacts FC–1, wire 496, contact 416*a*, contacts FR–5 and the coils of the relays TA and BR, in parallel, to the wire 478. Energization of the BR relay opens its normally closed contacts BR–1 and BR–2 and closes its normally open contacts BR–3 and BR–4. Consequently, the solenoid for the brake 167 is energized through the contacts BR3 and BR–4 releasing the brake and thus allowing the worm 163, the worm wheel 164 and the feed screw 155 to rotate freely. The clutch 75 has remained in engagement since the contacts CL–1 are open holding the solenoid 191 deenergized so that air pressure is not supplied to the cylinder 91 for the clutch, the latter being in communication with the exhaust port 98. The continued rotation of the worm 152 and the nut 154 by means of the shaft 114 will, however, no longer cause feeding movement of the work head because the feed screw 155 is now free to turn so that there is no relative movement between it and the nut. Consequently, the work head stands still while the work continues to rotate being driven by the worm 141 and the worm wheel 142 operated by the shaft 114. Likewise, the hob remains in continuous rotation since the drive thereto has not been interrupted at the clutch 75.

The relay TA is a part of the adjustable timer 417 which has been set to provide a predetermined "dwell" before the relay TA is effective to operate its movable contact TA–1. After this "dwell" has elapsed the TA–1 contact will be moved opening the circuit to the relay CL and the coolant solenoid CS thus deenergizing these relays. Deenergization of the CL relay closes its contacts CL–1 thereby energizing the solenoid 191 for operating the valve 96 to supply air under pressure to the operating cylinder for the clutch 75 thus disengaging the latter. Therefore, the rotation of the work and hob are terminated. The deenergization of the CL relay also closes its CL–2 contacts thereby energizing the relay TR which operates a short time later to open the TR–1 contact with consequent deenergization of the FC relay. The deenergization of the FC relay opens its contacts FC–1, thus deenergizing the TA and BR relays. Deenergization of the BR relay opens the contacts BR–3 and BR–4 and closes the contacts BR–1 and BR–2 so that the brake 167 is again applied to the worm shaft 162 connected with the rapid traverse motor. Deenergization of the FC relay also closes its FC–3 contacts thus energizing the AS relay and the latter therefore closes its AS–1 and AS–2 contacts to energize the solenoid 282. The solenoid 282 therefore operates the valve 281 supplying air pressure to the chuck and tail stock mechanism for releasing the work.

The operator then removes the work and again presses the strat button thus closing the circuit to the DN relay through the contact 434*b* and the

FC–2 contacts as previously described. The FC–2 contacts insure that the DN relay cannot be energized by means of the start button until after the time interval provided by the TR relay to insure that the clutch has had time to completely release before the rapid traverse motor is energized through operation of the DN relay. When the DN relay has been energized as described, the work head moves rapidly back to its starting position as previously described, the cycle being completed and reinitiated in the same manner as before.

Conventional or "normal" hobbing with automatic return.—Automatic operation

When it is desired to have the work head returned to its initial or starting position after termination of the hobbing operation without again actuating the start button 411, the automatic return switch 415 on the cabinet 393 of the unit is set at its "on" position. This moves the movable contact 415*a* of the switch 415 into circuit opening position and contact 415*b* into circuit closing position, the circuit otherwise remaining as illustrated in Fig. 25. The operation of the unit is started as before by depressing the start button 411, the operation continuing as above described until the work head reaches its uppermost position at which time the switch 434 is moved to open the circuit through its contacts 434*a* and close the circuit through its contact 434*b*. The workpiece is, however, not released from the chuck and the tail stock mechanisms at this time since the DN–2 contacts are now operative in the AS relay circuit. Hence, as soon as the FC relay is deenergized by opening of the circuit through the TR–1 contact, a circuit is immediately closed through the DR–1 contacts, wire 482, contact 415*b* of the automatic return switch, wire 500, contact 414*b* of the hobbing selector switch, contact 434*b* of switch 434, contact 414*d* of the hobbing selector switch and the now closed contacts FC–2 and the coil of the DN relay to the wire 478. This energizes the DN relay so that the contacts DN–2 are opened substantially simultaneously with the closing of the contacts FC–3 in the circuit for the AS relay. Hence, the circuit to the AS relay is not closed for any appreciable length of time with the result that the valve 281 is not operated to supply air pressure for releasing the chuck and tail stock mechanisms.

The energization of the DN relay closes its contacts DN–3, DN–4, and DN–5 so that the work head is rapidly traversed back to its original position without the necessity of again operating the start button. When the work head reaches its starting position, the switch 434 is actuated by the projection 428 moving the contacts 434*a* and 434*b* to their positions illustrated in Fig. 25. This deenergizes the DN relay thus deenergizing the rapid traverse motor 160 and closing the DN–2 contacts thereby completing the circuit for energizing the AS relay. The latter now closes its AS–1 and AS–2 contacts operating the solenoid 282 which in turn actuates its valve 281 for supplying air pressure to the chuck and tail stock so that the workpiece is released. A new workpiece may be placed in the unit and the cycle started by again pressing the start button.

The provision of the contacts FC–2 in the circuit of the relay DN insures that the rapid traverse downwardly of the work head cannot occur until after sufficient time has elapsed to effect complete disengagement of the clutch. This time interval being provided, as above described, by the TR relay, the contact TR–1 of which controls the FC relay preventing the closing of the FC–2 contacts until a few seconds after the CL relay has been deenergized.

It will be observed that in this mode of operation the work head moves downwardly at the rapid traverse rate with the work retained in chucked relationship and is therefore carried back through the hob until the latter is moved rearwardly by the action of the cam slot 265 upon the cam roller 266.

Conventional or "normal" hobbing with "clean-up" and automatic return.—Automatic operation

A "dwell" may be provided in the work head movement at the end of the cutting operation to effect "clean-up" in conjunction with automatic return by setting both the automatic return switch 415 and the feed control switch 416 to their "on" positions prior to starting of the cycle. The operation is then the same as described for "normal" automatic operation with "clean-up" except that instead of operating the start button 411 to return the work head at the end of the "clean-up" operation this return is automatically effected as just described. As previously noted, this automatic return cannot begin until the FC–2 contacts are closed and these contacts cannot be closed until after the "clean-up" period has elapsed. This results from the fact that the TR–1 contact, which controls the FC relay, is operated by the TR relay and the latter is controlled by the CL–2 contacts operated by the CL relay, the CL relay in turn being controlled by the contact TA–1 of the adjustable timer.

Conventional or "normal" hobbing.—Manual operation

In initially setting up the machine it is frequently desirable to operate a hobbing unit without rotation of the turret. This may be readily effected in the present machine by depressing the start buttons 385 and 387 for energizing the cut motor 59 and the coolant pump motor 447 as previously described. The operator next momentarily depresses the stop button 412 thus energizing relay DR causing the latter to close its normally open contacts DR–1, DR–2 and DR–3. Closing of the contacts DR–1 provides a holding circuit for relay DR, while closing of the contacts DR–3 closes the circuit for energizing the AS relay. Energization of the AS relay causes the latter to close its contacts AS–1 and AS–2 thereby energizing the solenoid 282 operating the valve 281 for applying air pressure to the chuck and tail stock mechanisms in a direction for releasing the chuck and retracting the tail center. The operator then inserts a workpiece between the chuck and tail center and moves the toggle switch 413 to its "Man." (manual) position and also positions the coolant switch knob 419 to its "on" position. Operation of the toggle switch 413 moves the contacts 413*a* and 413*b* of the latter into circuit closing and circuit opening positions respectively. The circuit for the AS relay is now open at the contact 413B deenergizing this relay and thus causing the AS–1, AS–2 contacts to open with consequent deenergization of solenoid 282 and reversal of the position of the valve 281. Therefore, the chuck and tail center mechanisms are now operated by air pressure into work gripping positions.

The operator next presses the start button 411 for the hobbing unit. The switch 410, which is

operated by rotation of the turret, is now bypassed by the contact 413a so that operation of the unit is initiated without rotation of the turret. That is to say, operation of the start switch 411 energizes the FR relay, as before, closing the contacts of the latter which now provide a circuit for relay ER from the wire 484 through the contacts FR–1, wire 488, contact 413a of the switch 413, wire 489 and through the coil of the relay ER to the wire 478. Energization of the relay ER initiates the rapid traverse movement of the work head to bring the workpiece into hobbing position as previously described under the heading of "Conventional or 'normal' hobbing.—Automatic operation." Likewise, the workpiece is hobbed and the work head is stopped at its uppermost position as previously described, the movement of the work head and the hobbing of the workpiece being under control of the FR relay, energization of which is terminated when the work head reaches its uppermost position by movement of the contact 434a of the work head actuated switch 434 to circuit opening position.

This actuation of switch 434 breaks the circuit for the FR relay causing the latter to open its contacts FR–1 thereby deenergizing the ER relay with constant deenergization of the CL relay, which controls the clutch 75, as previously described. The work piece is not, however, released when the work head has reached its uppermost position as before since the circuit for energizing the AS relay has been opened at the contact 413b of the switch 413. In order to release the workpiece it is now necessary to move the switch 413 back to its "Auto." (automatic) position thereby closing the circuit through the contact 413b to the AS relay, energizing the latter and causing release of the workpiece as previously described. The work head is then returned to its initial position by again operating the start button 411, the operation of the apparatus in this part of the cycle being the same as that described before.

The automatic "clean-up" feature may be employed with manual operation by setting the feed control switch 416 to its "on" position, "clean-up" operation then being the same as described above for automatic operation with "clean-up."

If the circuit has also been set for automatic return by moving the switch 415 to its "on" position and the operator has also set the switch 413 for manual operation, the work head will automatically return to its starting position after the hobbing has been completed, the workpiece being carried back through the hob since the circuit for operating the AS relay to effect release of the work is opened at the contact 413b.

"Climb" hobbing.—Automatic operation

The improved hobbing machine of this invention is also capable of being operated for hobbing in accordance with the "climb" method by setting the hob selector switch 414 to its "climb" position, and by interposing an idler gear in the feed train comprising the gears 143, 144, 147 and 148 to change the direction of rotation of the worm 152, the worm wheel 153 and the feed nut 154. Setting of the hob selector switch 414 for "climb" hobbing moves the contacts 414a, 414b, 414c, 414d, 414e and 414f from their positions as shown in Fig. 25 and into engagement with the stationary contacts 501, 502, 503, 504, 505 and 506, respectively. Assuming that the operation is to be effected automatically and without "clean-up" or automatic return, the switch 413 is set to its "Auto." position and switches 415 and 416 are set to their "off" positions.

Operation of the hobbing machine is now started as before by depressing the start buttons 383, 385 and 387 thus energizing the rotation motor 35, cut motor 59 and the coolant pump motor 447. As the turret begins its rotation the operator also operates the coolant switch knob 418 to its "on" position and presses the hob unit start button 411. Operation of the start switch 411 now closes a circuit from the wire 476 through the contacts 436b, 479, 412a, wire 485, contact 411a, wire 499, wire 500, contact 414b, contact 502, wire 507, contact 434a, contact 414c, contact 503, and through the FC–2 contacts and the coil of the DN relay to the wire 478. The DN relay is therefore energized closing its contacts DN–1, DN–3, DN–4 and DN–5 and opening its contacts DN–2. Closing of the contacts DN–1 provides a holding circuit for the DN relay about the start switch, while closing of the contacts DN–3, DN–4 and DN–5 energize the rapid traverse motor 160, the direction of the current thus supplied to the motor being reversed at the contacts 505, 414e and 506, 414f so that the motor is energized to rotate in a direction which moves the work head upwardly. Current is also supplied through the normally closed contacts BR–1, BR–2 to the solenoid for brake 167, releasing the latter.

The work head therefore rapidly traverses to its uppermost position and during this motion the cam 426, carried by the work head, operates the switch 432 to move its lower contact 432b into circuit closing position and to open the circuit through the upper contact 432a. In the latter portion of this movement of the work head, the cam slot 265 allows the hob head to "in-feed" but no hobbing is effected at this time since no workpiece has as yet been placed in the machine. At the top of the travel of the work head the projection 429 thereon operates the switch 434 opening the circuit through the contact 434a and moving the contact 434b into circuit closing position. Opening of the circuit through the contact 434a deenergizes the DN relay with consequent stopping of the rapid traverse motor 160 and re-application of the brake 167. The projection 429 is so positioned that this action occurs after the work head has been elevated high enough so that a workpiece positioned therein will clear the "in-feed" but before the cam roller 266 solidly abuts the lower end of the cam slot.

The operator now momentarily depresses the stop button 412 thereby closing a circuit through its contact 412b from the wire 480 to the wire 481 and through the wires 482 and 483 to energize the DR relay thus closing the contacts DR–1, DR–2 and DR–3 of the latter. Closing the contacts DR–1 provides a holding circuit for the DR relay while closing of the DR–3 contacts close a circuit for energizing the AS relay. Energization of the AS relay closes the contacts AS–1 and AS–2 energizing the solenoid 282 thus causing the valve 281 to supply air pressure to the chuck and tail stock mechanisms moving these mechanisms to disengaging positions. A workpiece is now inserted between the chuck and tail center and the start button 411 is again momentarily actuated. Actuation of the start button 411 now closes a circuit through its contact 411a, wire 486, contact 414a, contact 501, contact 434b, contact 414d, contact 504, wire 508 and wire 487 to and through the FR relay to the wire 479. Hence, the FR relay is energized causing it to

close its contacts FR–1, FR–2, FR–3 and open its contacts FR–4 and FR–5. Closing of the contacts FR–1 and FR–2 provide a holding circuit for the relay FR while opening of the contacts FR–4 opens the circuit to the relay AS. This opens the AS–1 and AS–2 contacts thereby opening the circuit to the solenoid 282 so that the air valve 281 is operated to supply air pressure to the tail stock and chuck mechanisms to effect gripping of the workpiece.

As the turret rotates, due to the operation of the motor 35, the stationary cam 421 at the top of the machine operates the switch 418 of the unit to momentarily close the contact 418*a*. This energizes the ER relay through the contacts FR–1, DR–2, 418*a* and wire 489. Energization of the ER relay closes its contacts ER–1, ER–2 and ER–3 and opens its contacts ER–4. Closing of the contacts ER–1 provides a holding circuit for the ER relay about the contact 418*a* so that when the switch 418 has moved past the stationary cam the opening of the contact 418 will not cause the relay ER to be deenergized. Since the switch 432 has been moved to bring its contact 432*b* into circuit losing position during the movement of the work head to its uppermost position, closing of the contacts ER–2 now provides a circuit from the wire 484 through contacts 372*a*, contacts ER–2, wire 490, contact TA–1, contact 432*b*, and wire 498 for energizing the CL relay. A parallel circuit is also provided through the contact 419*a* to energize the CS solenoid. Consequently, the clutch 75 is engaged and coolant is supplied to the hobbing unit in the same manner as previously described for "normal" hobbing. Energization of the CL relay has also opened the CL–2 contacts so that the FC relay is now energized through the contacts 372*a*, ER–2, ER–3, wire 496 and the TR–1 contact. Energization of the FC relay closes its contacts FC–1 and opens its contacts FC–2 and FC–3.

The work head begins moving downwardly at the feeding rate and the hob and work spindles are rotated. Since the hob head is now at its "in-fed" position, hobbing begins and continues as the work head moves downwardly until the cam 426 causes the switch 432 to move its contacts 432*a* and 432*b* back to the position shown in Fig. 25. This deenergizes the CL relay with consequent disengagement of the clutch 75 and closing of the coolant supply valve 298. Deenergization of the CL, relay by movement of switch 432, has also closed the contacts CL–2 thereby energizing the TR relay, and hence the latter operates its TR–1 contact a short time thereafter to break the circuit to the FC relay. The TR–1 contact is held open by the continued energization of the TR relay through the contacts ER–2, ER–3 and CL–2 so that the circuit for the FC relay is held open. The deenergization of the FC relay opens its contacts FC–1 and closes its contacts FC–2 and FC–3. Closing of the FC–3 contacts does not, however, energize the AS relay since the FR–4 contacts are still held open by the continued energization of the FR relay. Consequently, the work is held by the chuck and tail center while the work head rapid traverses downwardly to its starting position. This latter operation is effected by closing of the circuit for the RU relay through the contacts 372*a*, ER–2, wire 490, contact TA–1, and contacts 432*a* of switch 432. Energization of the RU relay closes its contacts RU–1, RU–2 and RU–3 for supplying current to the motor 160 and the solenoid of brake 167, the direction of current supplied to the motor being reversed by the contacts 414*e* and 414*f* of the hobbing selector switch 414 so that the motor 160 is energized for rotation in the direction which moves the work head downwardly. It will be understood that the position and shape of the cam plate are such that the cam roller 266 rides in the narrow portion of the cam slot 265 during this portion of the work head movement so that the hob is retracted from engagement with the workpiece and therefore the hob clears any projections on the workpiece adjacent the portion thereof which has just been hobbed.

When the work head reaches its lowermost or initial position the projection 428 operates the switch 434 back to its position as shown in Fig. 25 thus opening the circuit through the contact 434*b* deenergizing the FR relay. The deenergization of the relay FR opens its contacts FR–1, FR–2, FR–3 and closes its contacts FR–4 and FR–5. The opening of the contacts FR–1 deenergizes the relay ER which in turn opens its contacts ER–1, ER–2 and ER–3 thereby deenergizing the relay RU and the holding circuit for the relay ER. Deenergization of relay RU opens the circuit to the rapid traverse motor 160 and to the brake 167, causing the latter to reengage the worm shaft 162. The deenergization of the relay FR completes a circuit for energizing the AS relay through the FR–4, FC–3, and DR–3 contacts. Therefore, the AS–1 and AS–2 contacts are opened, deenergizing the solenoid 282 and thereby effecting release of the chuck and tail stock mechanisms, as previously described, so that the workpiece may be removed.

The contacts FC–2, which are now closed, prepare the circuit for a new operation. Therefore, when the start button 411 is actuated to start the new cycle, the work head now moves upwardly with its chuck and tail center in released positions. After the work head reaches its upper position, a new workpiece is positioned and the start button again actuated. This causes the workpiece to be gripped and the work head to begin its feeding movement downwardly as previously described. As in the case of "normal" hobbing, it is necessary to actuate the stop button 412 to operate the chuck and tail center mechanisms only when initially starting the machine, since the relay DR remains energized throughout the normal operation of the machine.

As mentioned under "normal" hobbing, the switch 372 is controlled by the extremes of axial movement of the hob spindle 41 in order to indicate when the hob should be replaced or reground and also to prevent further use of the unit until the spindle has been retracted to its initial position after it has reached its extreme forward position. In the event the hob has advanced to its extreme forward position, thereby actuating the switch 372 to open the contacts 372*a* and to close the contacts 372*b* thereof, during a cycle of operation, the cycle is not interrupted but will continue to completion. This is due to the fact that the contacts FC–1 are closed while the CL relay is energized for effecting engagement of the clutch 75, and these contacts FC–1 provide a circuit from the wire 484 through the contacts ER–3 to the wire 490 thus bridging the contacts 372*a*. Since the hob is shifted only when the clutch is engaged, this means that opening of the contacts 372*a* after the hob has started upon a hobbing operation, will not interrupt this operation which will continue to completion.

Moreover, if the hob be in operation when the switch 372 is operated, the ER–4 contacts will be open so that the light L will not be illuminated by closing of the contacts 372b. However when the work head is returned to its initial or lower position, the ER relay is deenergized by operation of switch 434. This closes the ER–4 contacts and hence the light L will be illuminated if the contacts 372b have been closed by the shifting of the hob spindle to its extreme forward position. Nevertheless, the work head may be returned to its upper position by again actuating the start button 411 even though the switch 372 has been operated to open its contacts 372a and close its contacts 372b. A new hobbing operation cannot be started however, since the open condition of the contacts 372a will now prevent a new energization of the CL relay. Returning of the hob spindle to its extreme retracted position will again close the contacts 372a and open the contacts 372b thus preparing the unit for a new cycle of operation and extinguishing the light L.

"Climb" hobbing with feed "clean-up."—Automatic operation

Automatic feed "clean-up" is not possible with a machine having a control circuit as illustrated in Fig. 25 when "climb" hobbing is used. This is due to the fact that when the hobbing has been completed by the work head moving to the point at which the switch 432 is operated back to its initial position illustrated in Fig. 25, the circuit for the CL relay is opened by this switch. Hence, the timer 417, which includes the TA relay and the TA–1 contact, cannot maintain a circuit for the CL relay which controls the clutch 75.

"Climb" hobbing with automatic return.—Automatic operation

Assuming that the DR relay has been previously energized and that the hobbing selector switch 414 has been set for "climb" hobbing, an actuation of the automatic return switch 415 to its "on" position immediately closes a circuit from the wire 480 through the contacts DR–1, wire 482, contact 415b, wire 500, contacts 414b and 502, wire 507, contact 434a, contacts 414c and 503, contacts FC–2 and through the DN relay to the wire 478. This energizes the DN relay closing its contacts DN–1, DN–3, DN–4, and DN–5. Closing the contacts DN–1 provides a holding circuit for the relay DN, while closing of the contacts DN–3, DN–4 and DN–5 energizes the rapid traverse motor 160 in a direction to elevate the work head since the contacts 414e and 414f are in engagement with the contacts 505 and 506, respectively, the brake 167 being released by current supplied through the normally closed contacts BR–1, BR–2. The energization of the DN relay also opened its contacts DN–2 which have been placed in the circuit of the AS relay by the movement of the contact 415a to its "on" position when the switch 415 was initially positioned. Hence, the AS relay is not energized so that the chuck and tail center are in work engaging positions while the work head rapid traverses to its upper position.

When the work head reaches its uppermost position the projection 429 actuates the switch 434, breaking the circuit through the contact 434a and closing the circuit through the contact 434b. This deenergizes the relay DN which opens its contacts DN–1, DN–3, DN–4 and DN–5 thus stopping the rapid traverse motor and reapplying the brake. The deenergization of the DN relay also closes the DN–2 contacts thus completing the circuit therethrough to the AS relay since the DR–3 contacts are held closed by the DR–4 relay. The resulting energization of the AS relay closes the contacts AS–1 and AS–2 thus energizing the relay 282 effecting release of the work gripping means as previously described. During the upward movement of the work head, the cam 426 thereon has reversed the position of the switch 432 moving its lower contact 432b into circuit closing position and opening the circuit through the contact 432a thus preparing circuits for effecting the hobbing operation. Also, the cam plate 259 has controlled the movement of the hob head so that the hob moves to its "in-fed" position.

The operator now inserts a workpiece between the chuck and tail center and presses the start button 411. This closes a circuit through the contact 411a of the start switch as above described under the heading of " 'Climb' hobbing—Automatic operation." Consequently, the FR relay is now energized, opening its contacts FR–4 and thereby deenergizing the AS relay and the solenoid 282 so that the chuck and tail center are actuated to work gripping positions. Also, the ER relay is energized, as before, so that the clutch 75 is engaged with the result that the work head is moved downwardly at a feeding rate with simultaneous rotation of the workpiece and hob. Hence, the work is hobbed, coolant or cutting fluid being supplied thereto during the hobbing.

When the work head has moved downwardly the predetermined distance for which the cam 426 is set, the latter actuates the switch 432 back to the position illustrated in Fig. 25 thus deenergizing the CL relay and thereby effecting disengagement of the clutch 75 so that the feed of the work head and rotation of the hob and workpiece are terminated. The supply of coolant is also terminated by opening of the circuit through the solenoid CS, all as above described. The actuation of switch 432 has also energized the RU relay so that the work head is now moved at the rapid traverse rate the remaining distance back to its original starting position, the hob head being retracted by the cam slot 265, as previously described. When the starting position is reached, the projection 428 reversed the switch 434. This results in deenergization of relays FR, ER and RU thus terminating the rapid traverse movement of the work head in the downward direction. The movement of the switch 434 at this time causes the contact 434a to again close the circuit for the DN relay through the contact 415a of the automatic return switch so that the work head immediately is rapid traversed upwardly again, carrying with it the workpiece firmly gripped by the chuck and tail stock since the DN–2 contacts are opened substantially simultaneously with the closing of the FR–4 and FC–3 contacts so that the circuit to the AS relay is not completed at this time. However, when the work head again reaches its uppermost position and is stopped by the projection 429 moving the switch 434 to break the circuit to the DN relay, closing of the contacts DN–2 of the latter now closes a circuit for energizing the AS relay with consequent release of the workpiece. Hence, the hobbed workpiece may be removed and a new workpiece inserted, the cycle being repeated by simply depressing the start button 411.

"Climb" hobbing.—Manual operation

When it is desired to employ the hobbing machine for "climb" hobbing but without rotation of the turret, the operation is effected by initially actuating the start buttons 385 and 387 thereby energizing the cut motor 59 and the motor 447 for the coolant pump. With the hobbing selector switch 414 set for "climb" and the switches 415 and 416 set to their "off" positions, the operator presses the start button 411. The operation will then be the same as that described for "climb" hobbing, automatic operation since the DN relay is energized through the start switch contact 411*a* thus causing the work head to rapid traverse to its uppermost position. Since the manual switch 413 has not yet been set to its manual position, a circuit is provided through the contacts DR–1, contact 413*b*, 415*a*, FR–4, FC–3 and DR–3 for energizing the AS relay. Therefore, the AS relay is energized so that its AS–1, AS–2 contacts are closed energizing the solenoid 282 and thereby operating the valve 281 to release the chuck and tail center. A workpiece is now inserted and the chuck and tail center are operated to work gripping positions by moving the switch 413 to its manual position. This breaks the energizing circuit for the AS relay at the contact 413*b* with the result that the solenoid 282 is deenergized so that valve 281 now drops back to the position in which air pressure is supplied to the chuck and tail stock mechanisms for gripping the work.

The operator then presses the start button 411. This completes a circuit through wires 486, contacts 414*a*, 501, 434*b*, 414*d*, 504, wire 503, wire 467 and the coil of the FR relay to the wire 478. Thus the FR relay is energized which in turn energizes the ER relay, the rotation controlled switch 418*a* being bypassed by the contact 413*a* of the manual switch. The energization of the ER relay closes the circuit through the switch 432 for the CL relay as has previously been described in detail. The work head therefore moves downwardly and a hobbing operation is performed upon the workpiece, as before, until the cam 426 actuates the switch 432 to deenergize the clutch relay CL and energize the RU relay thus disengaging the clutch and energizing the motor 160 to move the work head downwardly at rapid traverse rate. When the work head reaches its lowermost position, the projection 423 operates the switch 434 to the position as illustrated in Fig. 25 thus deenergizing the circuits for the FR, ER and RU relays. Hence, the traverse movement downwardly is terminated. The AS relay is not energized due to the closing of the FR–4 contacts, however, since the circuit is open at the contact 413*b*. Hence, in order to remove the workpiece at this time it is necessary to restore the switch 413 to its automatic position. The work head is returned to its uppermost position by again operating the stop button 411.

If the switch 415 be set for automatic return when the switch 413 has been set for manual operation the work head upon reaching its lowermost position will immediately be rapid traversed upwardly without the necessity of manually actuating the start button 411. The workpiece will be carried back up through the hob due to the fact that the circuit to the AS relay is open at the contact 413*b* of the switch 413, the cam plate 259 controlling movement of the hob head as previously described. When the work head has returned to its uppermost position, the workpiece may be released by moving the switch 413 to its automatic position thus completing a circuit for energization of the AS relay with consequent release of the workpiece.

Summary

It will now be apparent, from the foregoing description of the present preferred embodiment of the invention that a new and improved hobbing machine has been provided in which the hob head is automatically moved towards and away from the work head in timed relationship with the relative vertical movements between these heads so that gear teeth, splines, or other machining operations may be performed upon a selected portion of a cam shaft or other workpiece which has outwardly extending projections on one or both sides of the selected portion. The mechanism for accomplishing this result is simple in construction yet accurate in operation and may either be provided as an attachment upon existing machines or incorporated in new machines during the construction of the latter. Moreover, the "in-feed" mechanism may be employed with either a single spindle machine or with various types of multiple spindle machines. Furthermore, the incorporation of the novel "in-feed" mechanism in a multiple spindle, turret-type machine, of the type illustrated and described, provides a plurality of operational units which are automatically operated to effect accurate hobbing or similar machine operations in accordance with either the "normal" or "climb" principles and upon those portions of workpieces which could not be so operated upon by prior automatic machines, the improved machine being provided with means to gradually axially shift the hob or other tool of each operational unit to compensate for wear and automatic controls being provided so that the operator is required only to load and unload the work and manipulate a relatively few electrical switches.

The illustrated embodiment of the invention is particularly useful for cutting helical gears or the like upon portions of cam shafts or similar workpieces, which portions are relatively inaccessible due to the presence of outwardly projecting cam lobes or the like which the hob or other tool must not contact. The present machine accurately effects the necessary inward and outward movements of the hob or other tool when operating upon such workpieces by positively controlling such movements of the hob in accordance with the relative vertical movement between the latter and the work spindle which supports the workpiece. In the event a worm gear is to be cut upon the workpiece there is normally no relative vertical movement between the hob and the workpiece. Nevertheless, the necessary in and out movement of the hob may be effected by a mechanism substantially like that which has been illustrated and described. Thus, the hob head is continuously urged towards the work head by the fluid pressure acting in cylinder 249, or by equivalent means. Likewise, the hob head is provided with a cam roller such as 266 for cooperation with a movable cam surface to control the movement of the hob head. The configuration of this cam surface will, however, differ from that illustrated for the cam slot 265 and will be such as to provide the desired rate of movement of the hob head. Also, the pinion 143 or one of the gears cooperating there-

with (see Fig. 7) will be removed so that the work head is not vertically moved when the clutch 75 is engaged to effect rotation of the hob and work spindles. Since the work head does not now move during the hobbing operation, the cam surface controlling the in and out movement of the hob head is moved by suitable gearing (not shown) operatively connected with the shaft 74.

While the invention has been illustrated and described as embodied in a machine for performing certain hobbing operations, it will be readily apparent that the invention is not limited thereto but may be embodied in machine tools for performing other machining operations by the substitution of suitable tools and actuating mechanisms in place of the bobs and hob shifting mechanisms. These as well as other modifications and adaptations, which may be made by those skilled in the art, are considered as embraced in the present invention. Hence, the invention is not confined to the particular construction illustrated and described but is limited only as required by the spirit and scope of the appended claims.

Having thus described my invention, I claim:

1. A machine tool of the character described comprising a frame, a rotatable tool spindle, a rotatable work spindle, means including vertical guideways on said frame slidably supporting said work spindle in a manner to permit movement of said work spindle relative to said tool spindle in a substantially vertical direction, means including substantially horizontal guideways on said frame slidably supporting said tool spindle for movement towards and away from said work spindle transversely of said vertical movement, means including interconnected gearing for rotating said spindles in timed relation to each other, means operatively connected between said frame and said work spindle supporting means for producing said relative vertical movement between said spindles, and separate means for moving said tool spindle horizontally in timed relationship with respect to the said relative vertical movement, the last-named means including a mechanical interconnection between movable portions of the supporting means for said spindles.

2. The combination as defined in claim 1 and further comprising means to adjust the initial position of said tool spindle towards or away from the work spindle transversely of said relative vertical movement.

3. The combination as defined in claim 1 and in which said last-named means includes means for maintaining the movable portion of said tool spindle supporting means at a predetermined location during a predetermined portion of said relative vertical movement between said work and tool spindles.

4. A machine tool of the character described comprising a frame, a rotatable tool spindle, a rotatable work spindle, means including guideways on said frame extending at substantially right angles to each other for supporting said spindles upon the frame in a manner to permit movement of each of said spindles at substantially right angles to each other, means including a common power source and interconnected gearing for rotating said spindles in timed relation to each other, means connected with said power source for moving one of said spindles along its guideways, means continuously urging the other spindle for movement in one direction along its guideways, and means carried by the supporting means of said work spindle

and cooperating with the supporting means for said tool spindle to control the movement of said other spindle in said one direction and to move the said other spindle in the opposite direction along its guideways in timed relationship with the movement of the said one spindle.

5. The combination as defined in claim 4 and in which the said means for controlling movement of said other spindle includes a cam surface mounted upon one of said supporting means and cooperating with a cam follower carried by the other of said supporting means.

6. A machine tool of the character described comprising a frame, a rotatable tool spindle, a rotatable work spindle, means including guideways on said frame extending at substantially right angles to each other for supporting said spindles upon said frame in a manner to permit movement of one of said spindles relative to the other in a vertical direction and horizontal movement of the other of said spindles, means including a common power source and interconnected gearing for rotating said spindles in timed relation to each other, means connectible with said power source for producing vertical movement of one of said spindles, fluid pressure means continuously urging the other spindle for horizontal movement in one direction transversely of the said one spindle, and interengaging means carried by the supporting means for the spindles to control the movement of the said other spindle in response to the action of the fluid pressure means and to horizontally move said other spindle in the reverse direction in opposition to the action of the fluid pressure means in timed relationship with respect to the said vertical movement between the spindles.

7. The combination as defined in claim 6 and further comprising means to adjust the initial position of said other spindle horizontally towards or away from said one spindle.

8. The combination as defined in claim 6 and in which the interengaging means includes a cam surface mounted upon one of said spindle supporting means for cooperation with a cam follower carried by the other of said spindle supporting means.

9. The combination as defined in claim 8 and in which said cam means is provided with a dwell such that a tool on said tool spindle engages a workpiece carried by said work spindle during a predetermined portion of said vertical movement.

10. A machine tool of the character described comprising a frame, a rotatable tool spindle and a rotatable work spindle independently supported upon said frame in a manner to permit movement of one of said spindles relative to the other in a vertical direction and horizontal movement of the tool spindle towards and away from said work spindle, means carried by said work spindle for supporting a workpiece thereon, selectively operable means for rotating the said spindles in timed relationship to each other and for moving one of the spindles relative to the other in a vertical direction at a relatively slow rate in timed relationship to the rotation of said spindles, selectively operative means for moving the said one of the spindles at a relatively rapid rate without rotation of the spindles, means to initiate operation of said means for producing vertical movement of said one spindle at said relatively rapid rate, means actuated by the vertical movement of said one spindle to automatically terminate the operation of said means for producing relatively rapid vertical movement and to initiate operation

of said means for rotating the said spindles and for moving the said one spindle vertically at the relatively slow rate, and means for moving said tool spindle horizontally towards and away from said work spindle in timed relationship with the vertical movement of said one spindle, the last-mentioned means including a mechanical interconnection between the supports for said spindles to control said horizontal movement in timed relationship with the vertical movement, whereby a tool on said tool spindle automatically effects a machining operation upon a workpiece supported upon said work spindle.

11. A machine tool of the character described comprising a frame, a rotatable tool spindle and a rotatable work spindle independently supported upon said frame in a manner to permit movement of one of said spindles relative to the other in a vertical direction and horizontal movement of the tool spindle towards and away from said work spindle, means carried by said work spindle for supporting a workpiece thereon, selectively operable means for rotating the said spindles in timed relationship to each other and for moving one of the spindles relative to the other in a vertical direction at a relatively slow rate in timed relationship to the rotation of said spindles, selectively operative means for moving the said one of the spindles at a relatively rapid rate without rotation of the spindles, means to initiate operation of said means for producing vertical movement of said one spindle at said relatively rapid rate, means actuated by the vertical movement of said one spindle to automatically terminate the operation of said means for producing relatively rapid vertical movement and to initiate operation of said means for rotating the said spindles and for moving the said one spindle vertically at the relatively slow rate, means continuously urging the tool spindle for horizontal movement in one direction relative to said work spindle, and means carried by the supporting means for the said work spindle to control the horizontal movement of the tool spindle in said one direction and to move the tool spindle in the opposite horizontal direction against the action of the continuously urging means in timed relationship with respect to the said vertical movement, whereby a tool on said tool spindle automatically effects a machining operation upon a workpiece supported upon said work spindle.

12. A machine tool of the character described comprising a frame, a rotatable tool spindle and a rotatable work spindle independently supported upon said frame in a manner to permit movement of one of said spindles relative to the other in a vertical direction and horizontal movement of the tool spindle towards and away from said

work spindle, means carried by said work spindle for supporting a workpiece thereon, selectively operable means for rotating the said spindles in timed relationship to each other and for moving one of the spindles relative to the other in a vertical direction at a relatively slow rate in timed relationship to the rotation of said spindles, selectively operative means for moving the said one of the spindles at a relatively rapid rate without rotation of the spindles, means to initiate operation of said means for producing vertical movement of said one spindle at said relatively rapid rate, means actuated by the vertical movement of said one spindle to automatically terminate the operation of said means for producing relatively rapid vertical movement and to initiate operation of said means for rotating the said spindles and for moving the said one spindle vertically at the relatively slow rate, fluid pressure means continuously urging the tool spindle in a horizontal direction towards the work spindle, a cam means carried by the supporting means for one of said spindles and cooperating with the supporting means of the other of said spindles to control the horizontal movement of said tool spindle towards said work spindle and to horizontally move the tool spindle away from said work spindle against the action of the fluid pressure means in timed relationship with respect to said vertical movement between the spindles, whereby a tool on said tool spindle automatically effects a machining operation upon a workpiece supported upon said work spindle.

13. A combination as defined in claim 12 and in which the said cam means includes a dwell portion for maintaining a predetermined engagement of a tool on the tool spindle with a workpiece carried by the work spindle during a predetermined portion of said relative vertical movement of the spindles.

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