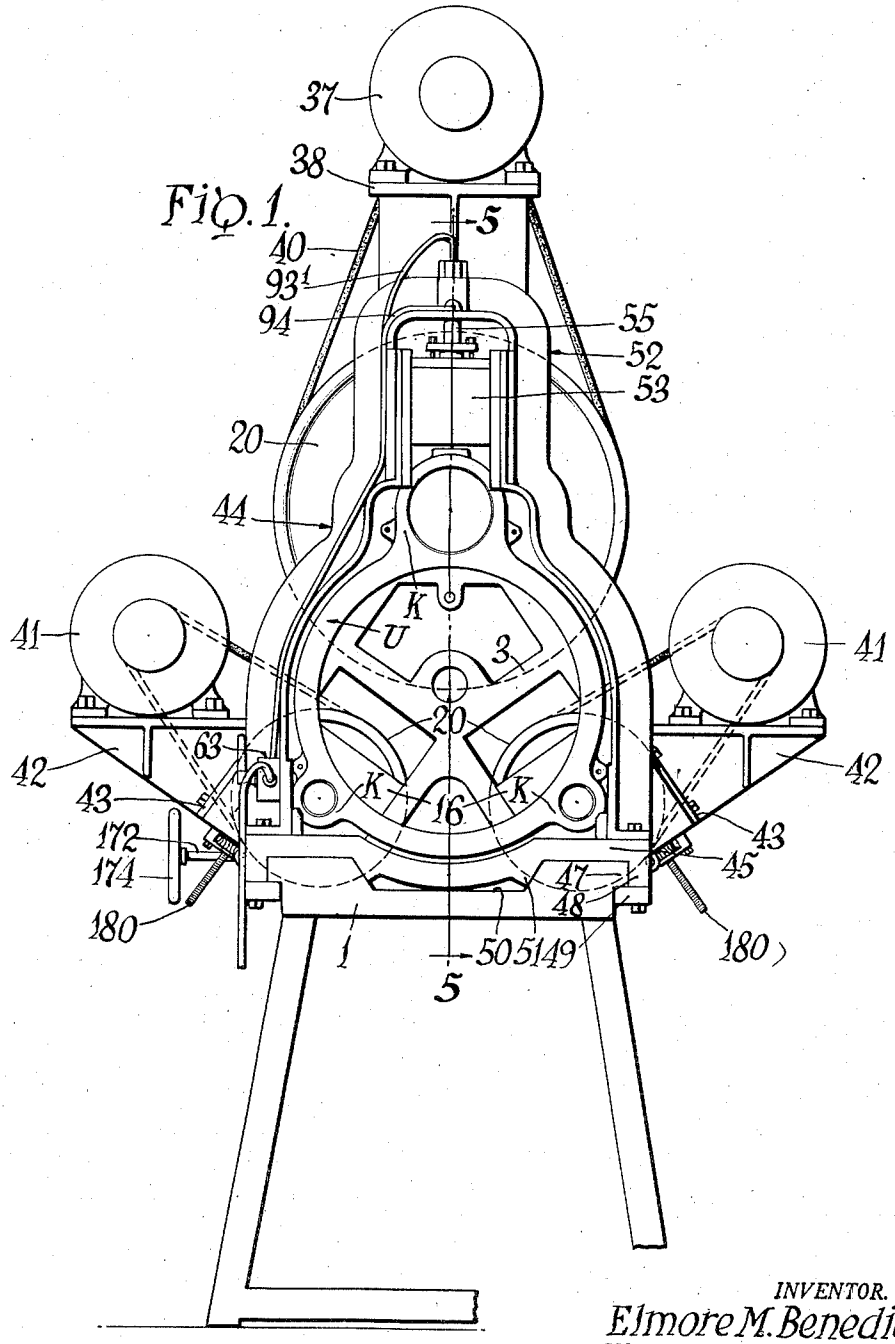
May 28, 1957 E. M. BENEDICT 2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 1

Fig. 1.



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May 28, 1957 E. M. BENEDICT 2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 2

Fig. 2.

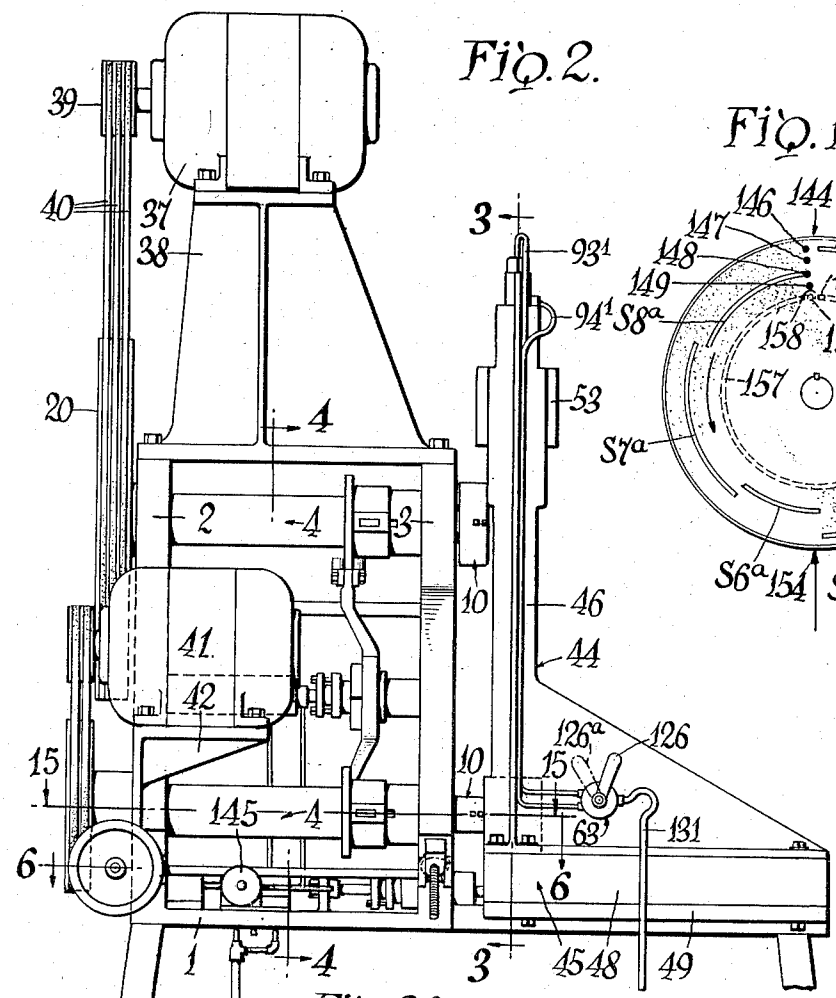


Fig. 12.

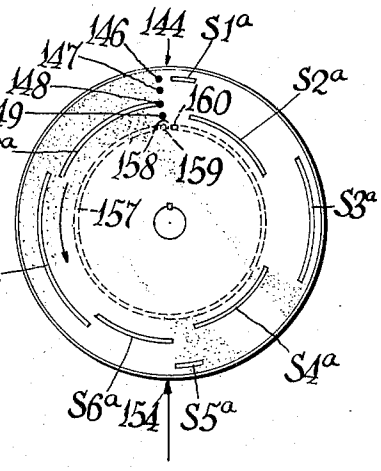


Fig. 26.

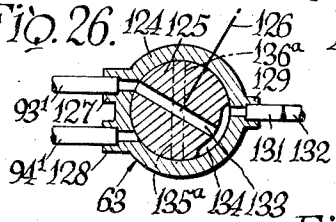


Fig. 27.

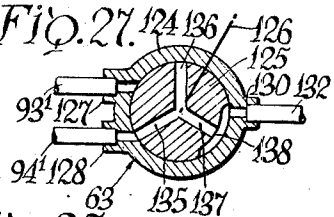
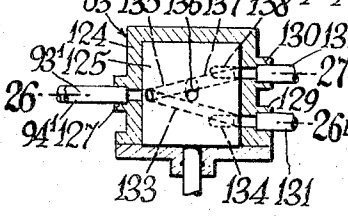


Fig. 25.



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May 28, 1957 E. M. BENEDICT 2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 3

Fig. 3.

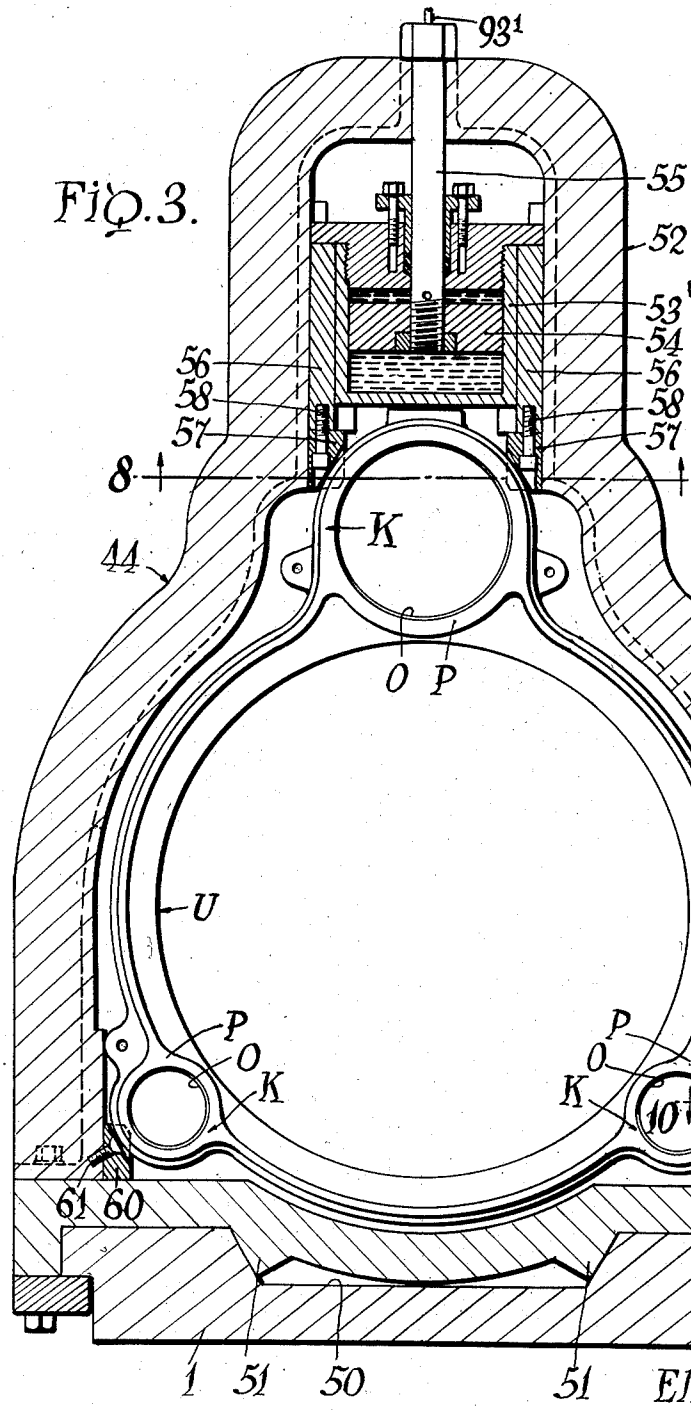


Fig. 8.

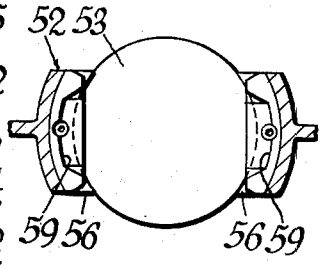


Fig. 10.

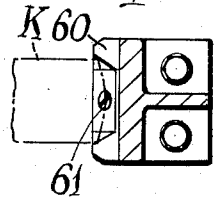


Fig. 7.

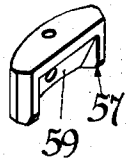
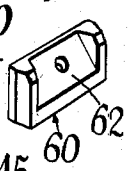


Fig. 9.



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May 28, 1957 E. M. BENEDICT 2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 4

Fig. 4.

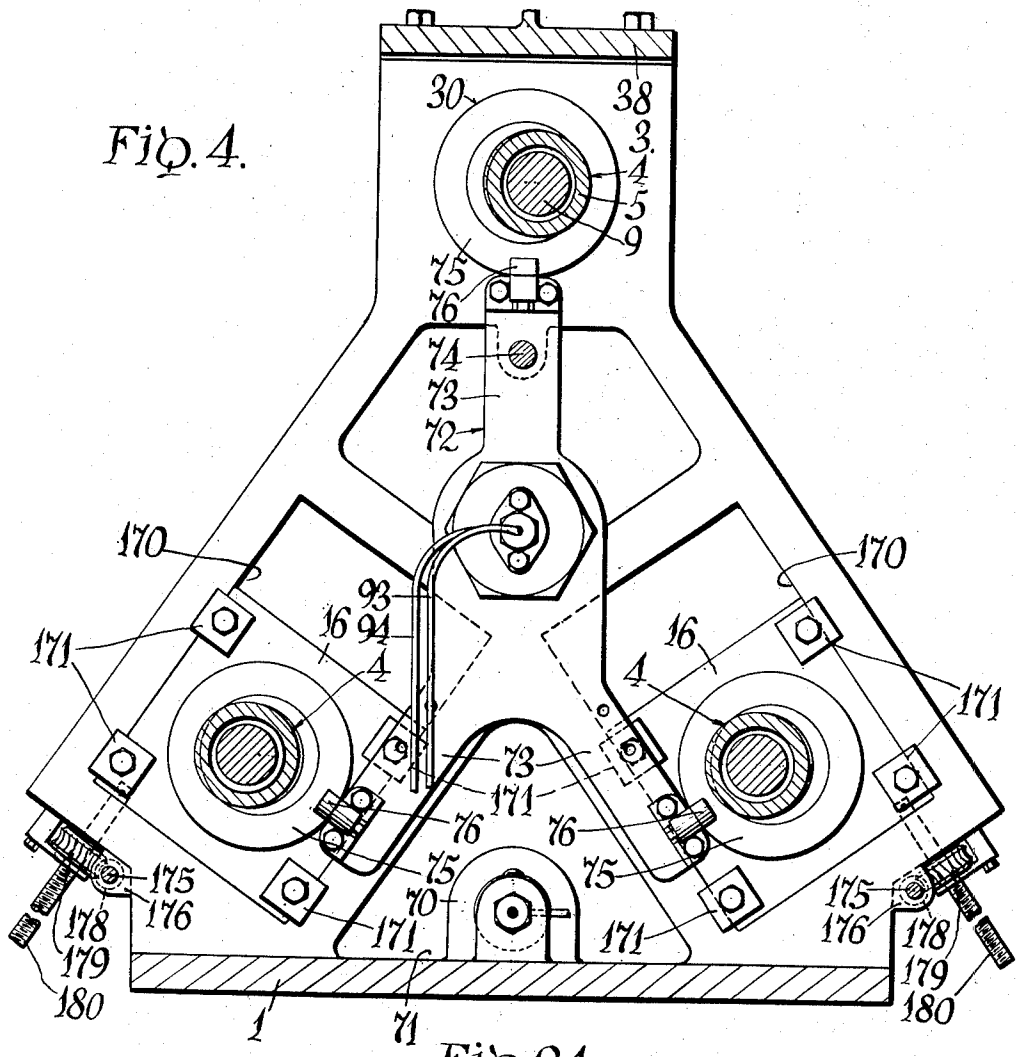
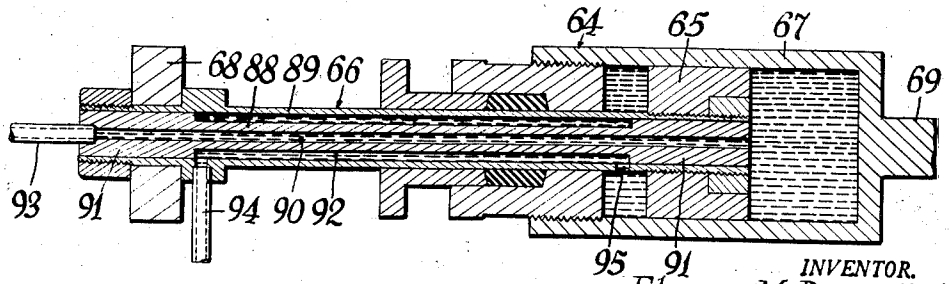


Fig. 24.



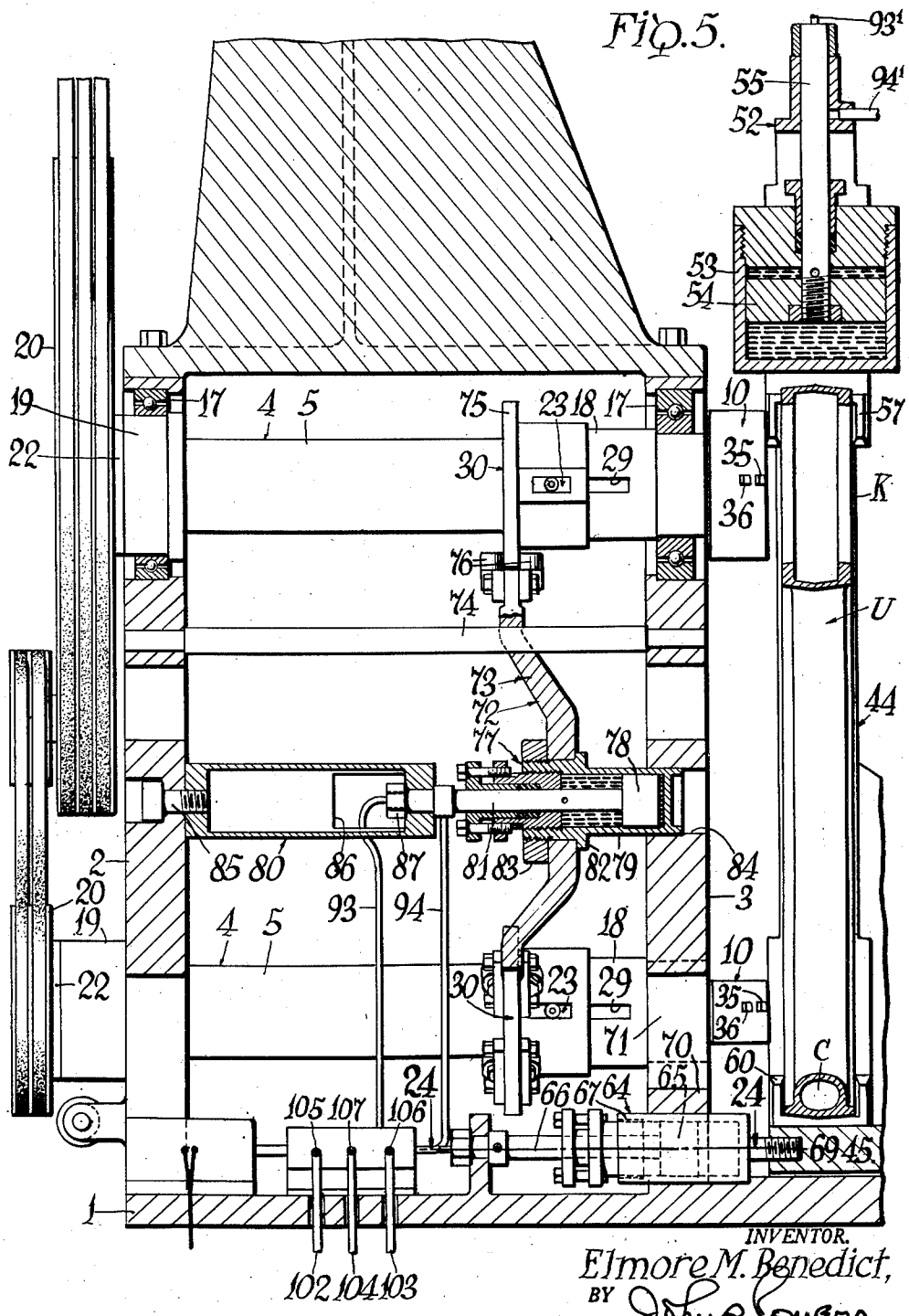
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MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 5

Fig. 5.



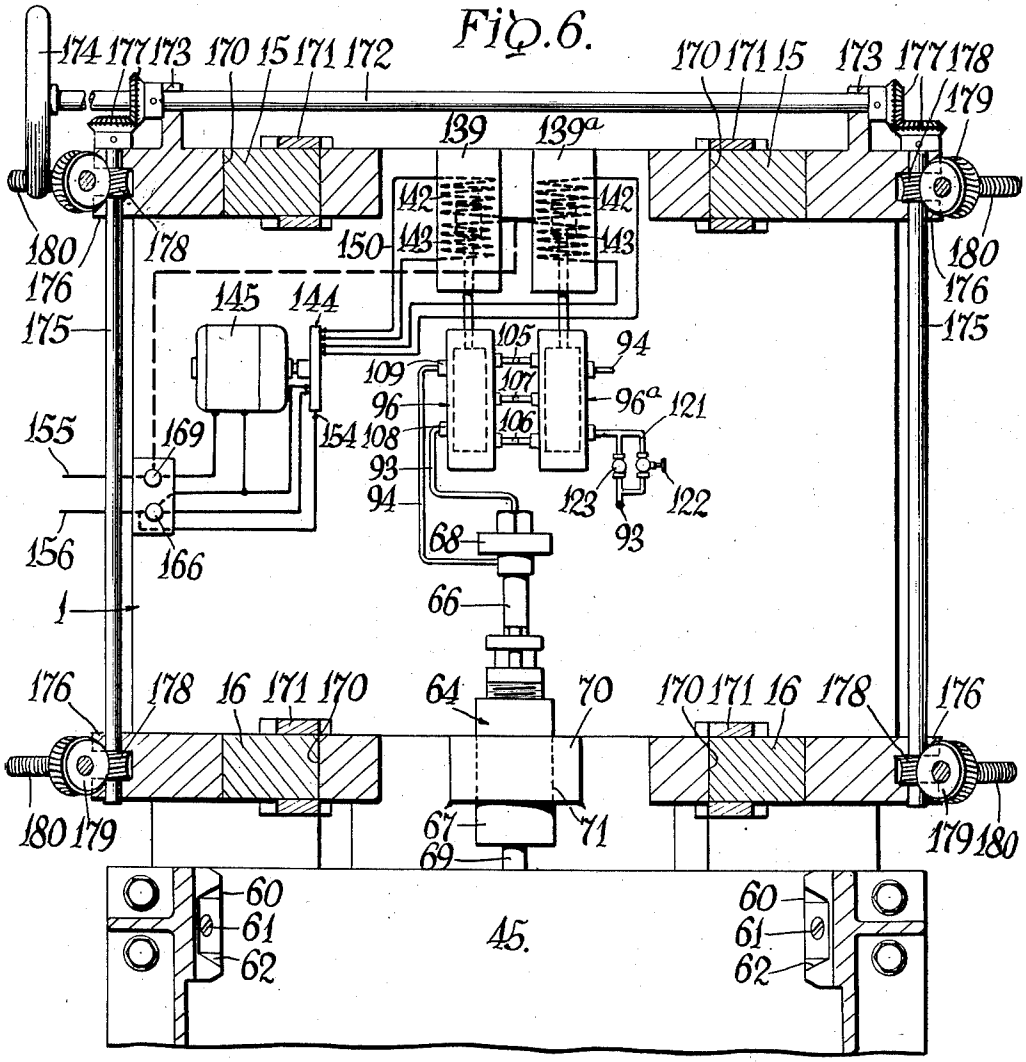
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MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 6

Fig. 6.



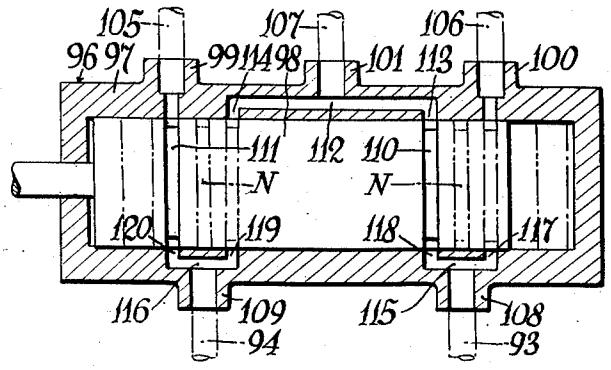


Fig. 11.

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May 28, 1957 E. M. BENEDICT 2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 7

Fig. 21.

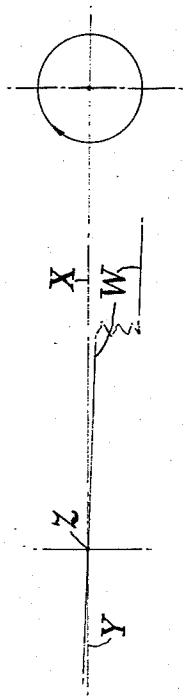


Fig. 22.

Fig. 23.

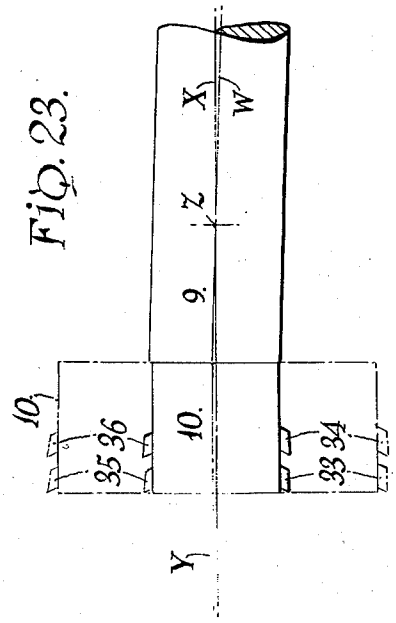


Fig. 29.

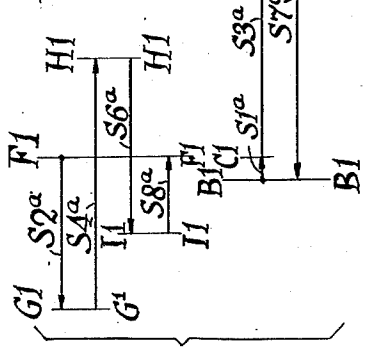


Fig. 30.

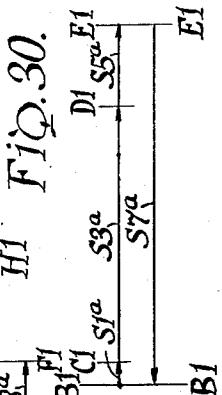


Fig. 13.

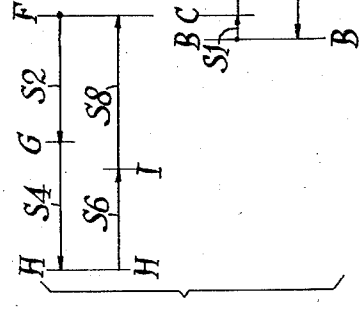
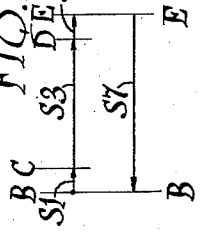


Fig. 14.



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May 28, 1957 E. M. BENEDICT 2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 8

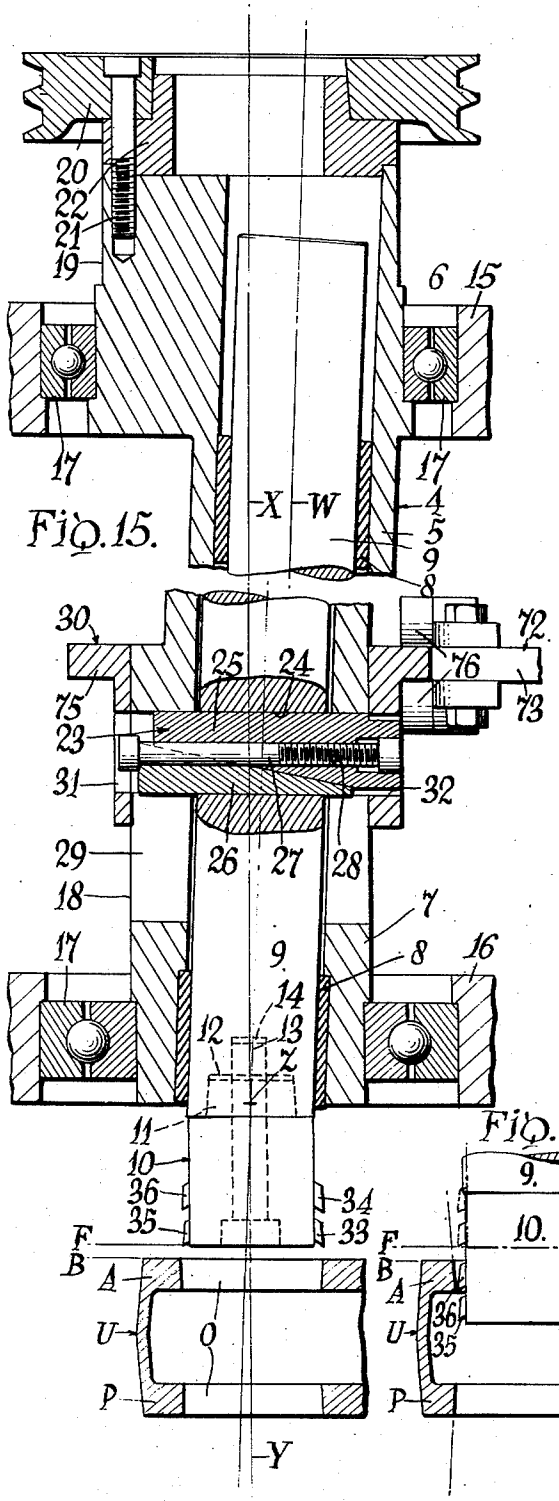


Fig. 15.

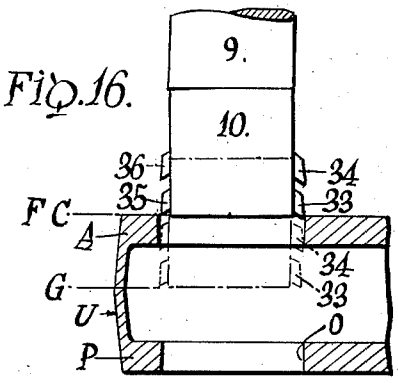


Fig. 16.

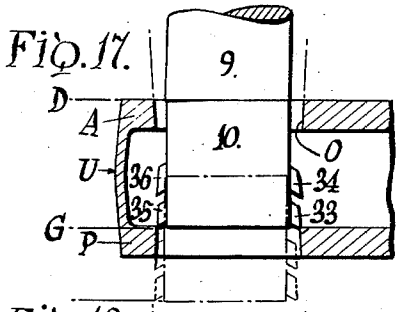


Fig. 17.

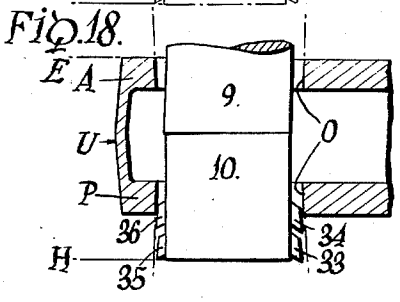


Fig. 18.

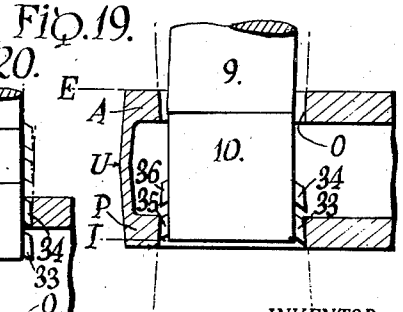


Fig. 19.

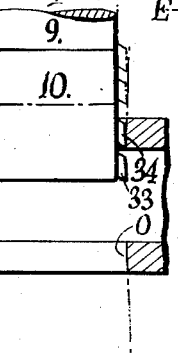


Fig. 20.

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May 28, 1957 E. M. BENEDICT 2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 9

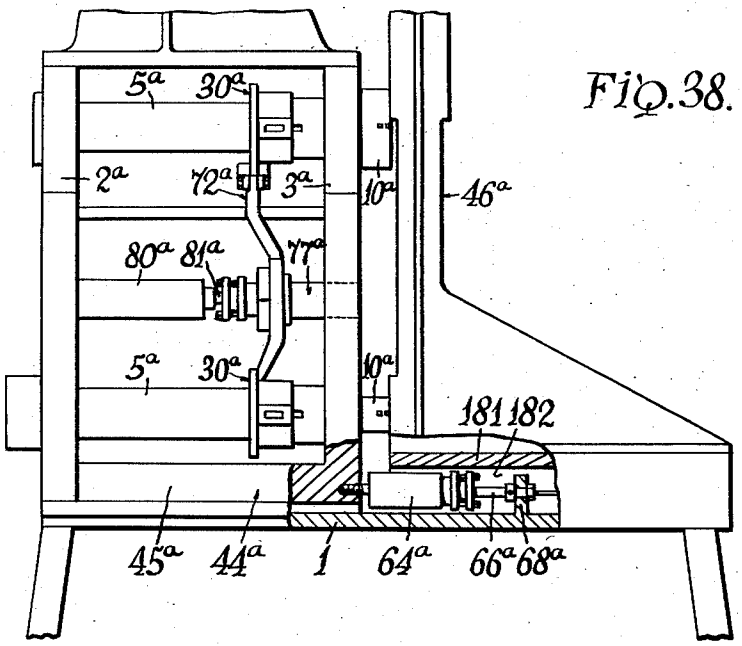


Fig. 38.

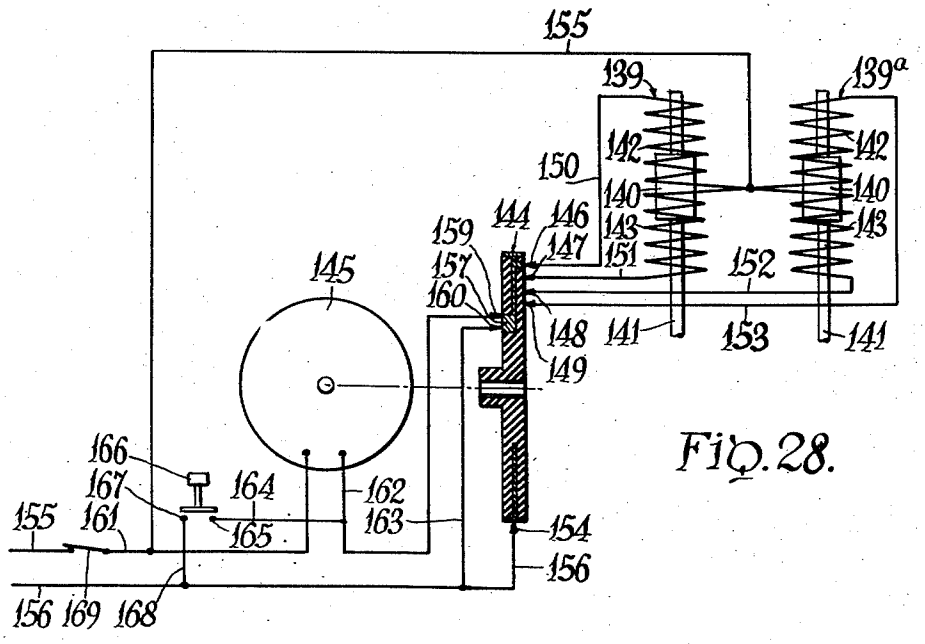


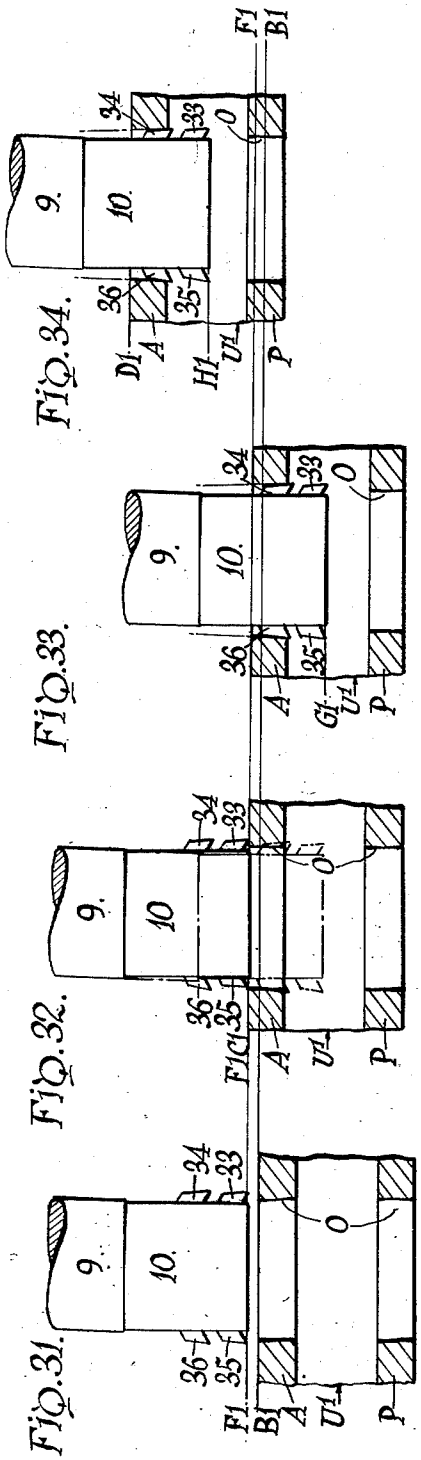
Fig. 28.

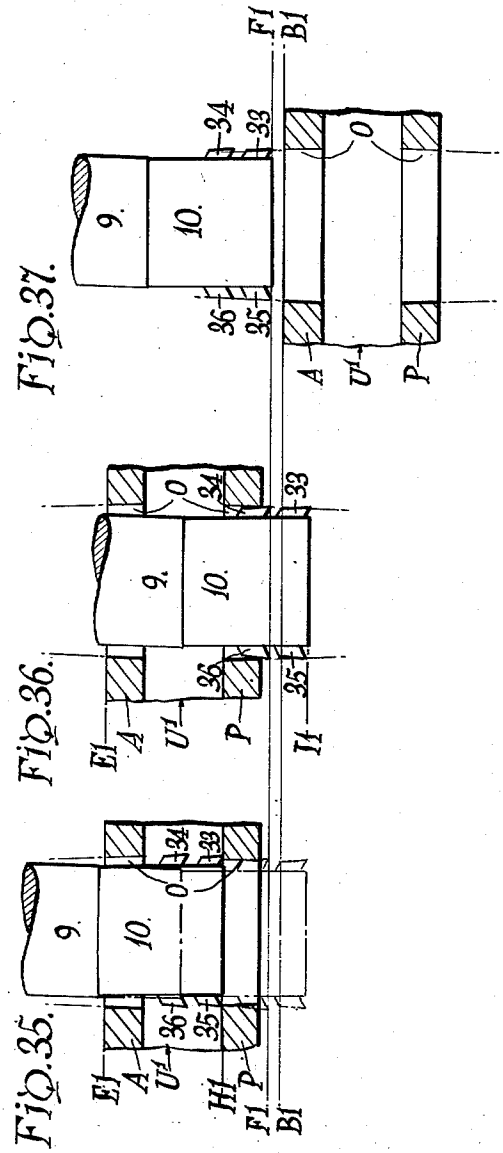
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MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 10



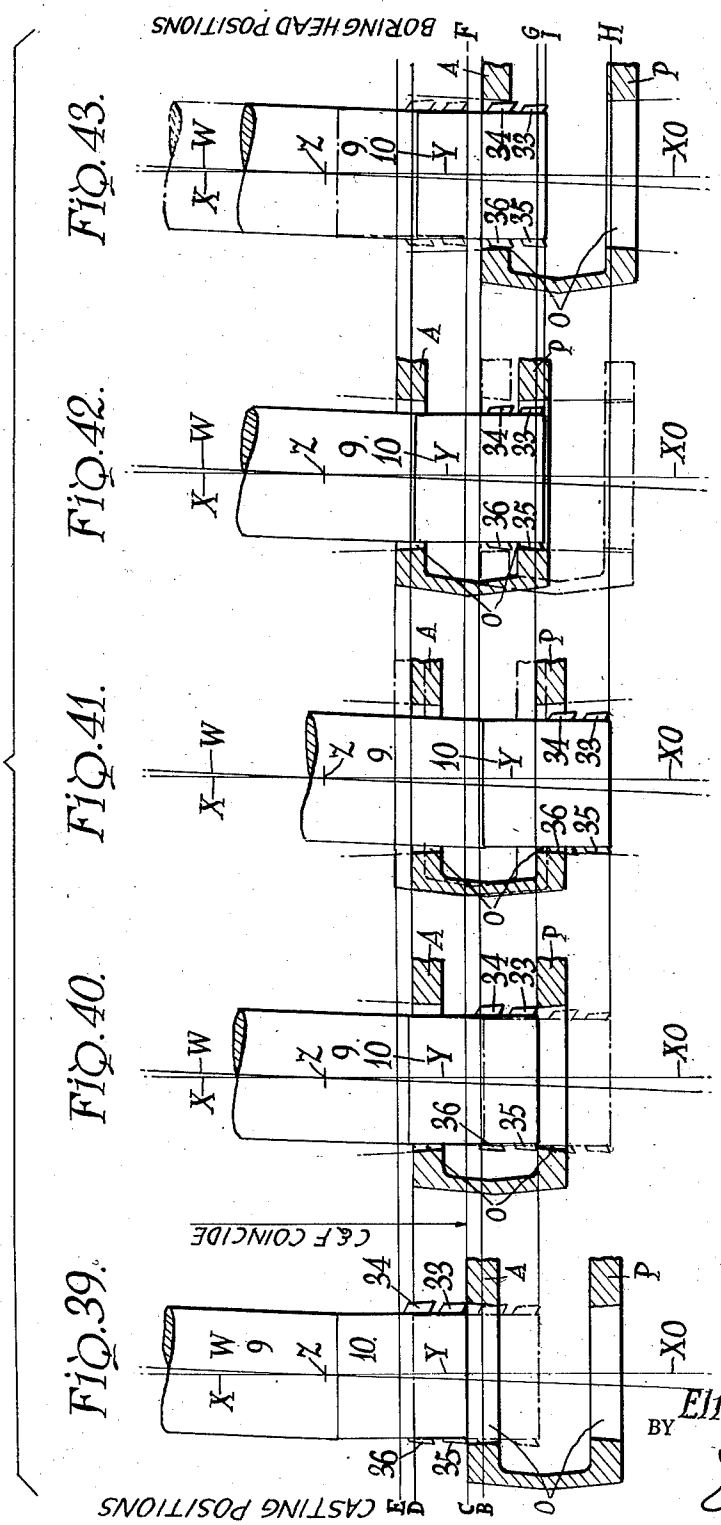


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MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Filed April 15, 1954 11 Sheets-Sheet 11



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United States Patent Office 2,793,545 Patented May 28, 1957

2,793,545

MACHINE FOR BORING OPPOSITELY TAPERING COAXIAL HOLES IN SPACED PARALLEL WALL PARTS

Elmore M. Benedict, Buffalo, N. Y.

Application April 15, 1954, Serial No. 423,374

17 Claims. (Cl. 77—3)

This invention relates to a machine for boring oppositely tapering coaxial holes in spaced parallel wall parts.

In prior practice oppositely tapering holes in parallel wall parts have been formed in separate and independent operations.

The principal object of the invention, as a matter of substantial economy of manufacturing operation, is to provide a machine in which the boring operation and the subsequent release of the work from the boring medium are accomplished serially in a sequence of steps involving relative movements of the various parts in what is essentially a single operation for tapering both of the holes.

The machine, among other essential features, includes a boring bar having a driving element and a boring head having diametrically oppositely located cutters, the cutters as oppositely located being for boring the tapers in the openings of the respective walls. In carrying out the above stated principal object the invention fundamentally provides for rectilinear positionally adjustable relative movements of the driving element and the work and movements of the boring head relatively both to the driving element and the work, certain of which movements involve the feeding of the cutters into and through the work and all of which movements are carried out in a cycle of operation involving a series of coordinated steps and an appropriate selection of the relation of the cutters for operation in a predetermined sequence.

As other essential features the driving element is arranged along an inclined axis and is rotatable about a major axis, preferably horizontal, and the boring head itself has an axis which extends in the same direction as the major axis and is carried by a part slidably and adjustably movable along the inclined axis. With these characteristics in mind further objects are to provide a machine having the capacity for appropriate selection of the directions and extents of the relative movements of the driving element, the boring head and the work, the durations of their periods of rest and the relative arrangement of the cutters, whereby, according to choice, the tapers may be bored with their minimum diameters in either mean or extreme relation and in either instance their degree of angularity may be varied from the maximum permissive degree.

A further object is to provide a machine of the character stated in which several pairs of alining oppositely tapering holes may be simultaneously bored.

As other essential elements the machine includes separate motors for effecting the steps of relative movement of the boring head and the work and a mechanism for controlling the operation of the motors in respect to the directions, extents and sequences of such movements. With these characteristics in mind a further object is to provide a mechanism for controlling the operation of the motors which has a governing element specifically designed for effecting the particular directions, extents and sequences of the steps of movement of the driving element, the boring head and the work which element may be replaced by a similarly functioning element of the same

general character and appropriately different specific design when, according to choice, the directions of the tapers cut by the machine are to be reversed or when the operation of the machine is to be limited to the boring of the taper only in the anterior wall.

A further object is to provide a machine of the character stated in which all operative phases, including the operations of the boring bars, positional adjustments of the various parts, and the operation of the mechanism for controlling the operation of the motors are effected by power.

The invention comprehends a machine having the above essential characteristics and otherwise characterized by novel features of structure and combination whereby the above objects are served.

In the example selected for illustration the structural element in which tapers are to be bored is a water filled unit of a sectional boiler but it will be understood that machines embodying the invention may be used for boring oppositely tapering coaxial holes in spaced parallel walls of elements of different design, that is to say elements designed as parts of various structural assemblies for different specific uses, for example, radiator units.

The drawings illustrate an embodiment of the invention which, as now considered, is preferred. In the drawings:

Figure 1 is a front elevation of a machine in accordance with the invention, with the work unit, i. e., the structural element, shown as positioned on its carrier.

Figure 2 is a side elevation of the machine.

Figure 3 is a vertical transverse sectional view on the line 3—3 of Figure 2.

Figure 4 is a vertical transverse sectional view on the line 4—4 of Figure 2.

Figure 5 is a vertical sectional view on the line 5—5 of Figure 1.

Figure 6 is a horizontal sectional view on the line 6—6 of Figure 2.

Figure 7 is a perspective view of one of two similar devices for clamping engagement with the upper portion of the structural element upon which the machine operates.

Figure 8 is a detail horizontal sectional view on the line 8—8 of Figure 3.

Figure 9 is a perspective view of one of two similar devices for clamping engagement with the lower portion of the structural element upon which the machine operates.

Figure 10 is a detail horizontal sectional view on the line 10—10 of Figure 3.

Figure 11 is a horizontal sectional view of one of two similarly constructed and acting valves for controlling respectively the movements of the carriage for the structural element and the movements of the slidably mounted spindles of the boring bars, the valve shown in this figure being the valve which controls the movements of the carriage.

Figure 12 is an elevation of the governing element which is shown in the form of a rotatable electrical contact-carrying disk.

Figures 13 and 14 are complementary graphs as indicated by the bracket showing the sequence of the steps of movement of the boring head and the work when the tapers to be cut have their minimum diameters in mean relation and their maximum diameters in extreme relation, Figure 13 being a graph of the operative movements of the boring head and Figure 14 a graph of the operative movements of the work.

Figure 15 is a central horizontal sectional view on the line 15—15 of Figure 2 of one of the boring bars and the associated parts, the boring head and the work being diagrammatically shown in their relative positions prior to the commencement of the boring operations. It will be

understood that the several boring bars are of similar construction.

Figures 16 to 20 are a series of diagrammatic views of similar character in the same horizontal plane as Figure 15 which, like the diagrammatic showing of Figure 15, assume the boring of tapers in the two walls in which the minimum diameters are in mean relation and the maximum diameters are in extreme relation. These figures show the relative positions of the boring head and the work in the different steps of operation. In these figures, the work is shown in section taken in the same plane in which it is shown in Figure 15.

Figure 16 shows the relative positions of the boring head and the work when the work has been advanced to a position in which the outer or anterior face of its anterior wall is substantially coincident with the face of the boring head and the opening in the anterior wall (the opening being formed in the molding operation) to be cut with a taper is presented to the cutters.

Figure 17 shows the relative positions of the boring head and the work when the work has been shifted from the position shown in Figure 16 to a position in which the inner or anterior face of the posterior wall is substantially coincident with the face of the boring head and the opening in the posterior wall (the opening being formed in the molding operation) is presented to the cutters.

Figure 18 shows the boring head and the work when the work has been shifted from the position shown in Figure 16 to a position in which the posterior or outer face of the posterior wall is located at a suitable distance in advance of the leading or active edges of the cutters in preparation for the movement of the boring head through an initial retractile step, thereby to pull all of the cutters through the tapered opening which has been cut in the posterior wall.

Figure 19 shows the work in the same position in which it is shown in Figure 18 but with the boring head at the completion of its first step of retractile movement.

Figure 20 shows the work as shifted from its position shown in Figure 19 back to its original position which is shown in Figure 15. This movement of the work enables the boring head to be moved back to its original position as shown in broken lines.

Figure 21 is a diagram showing the concentric rotation of the axial center of the spindle which carries the boring head about the fixed axis of rotation of the boring bar.

Figure 22 is a diagram showing the relation of the central axis of the spindle which carries the boring head, the fixed central axis of rotation of the boring bar and the central axis of the boring head when the work and the boring head have been brought into the relation shown in Figure 16.

Figure 23 is a diagram showing the manner in which the central axis of the boring head moves away from the fixed central axis of rotation of the boring bar when the boring head is advanced in the direction of the axis of its spindle in the course of the cutting operations.

Figure 24 (Sheet 4) is a horizontal section on the line **24—24** of Figure 5, showing details of the fluid motor for effecting the movements of the carrier for the structural unit.

Figure 25 is a horizontal sectional view showing details of the manually operated valve for controlling the operation of the work clamping means, the valve body being shown in elevation.

Figure 26 is a vertical sectional view on the line **26—26** of Figure 25 showing the path of flow of the operating fluid to effect the clamping action.

Figure 27 is a vertical sectional view on the line **27—27** of Figure 25 showing the valve body in the same position and the path of return flow of the operating fluid.

Figure 28 is a wiring diagram showing the solenoids for the operation of the valve bodies of the fluid motors illustrated in Figures 5 and 24 and the motor driven contact carrier which controls the energization and de-energization of the solenoids.

Figures 29 and 30 are complementary graphs as indicated by the bracket showing the sequences of steps of movement of the boring head and the work when the tapers to be cut have their minimum diameters in extreme relation and their maximum diameters in mean relation, Figure 29 being a graph of the operative movements of the boring head and Figure 30 a graph of the operative movements of the work.

Figures 31 to 37 are a series of diagrammatic views of similar character showing the relative movements and positions of the boring head and the work when the tapers are to be cut with their minimum diameters in extreme relation and their maximum diameters in mean relation. The diagrams of these views are of the same general character as the diagrams of Figures 15 to 20, the work being shown in section in the same plane in which it is shown in Figures 15 to 20.

Figure 31 shows the boring head and the work in their relative positions prior to the commencement of the boring operations and after their completion.

Figure 32 shows the relative positions of the boring head and the work when the work has been advanced to a position in which the outer or anterior face of the anterior wall is substantially coincident with the end face of the boring head and the opening in the anterior wall is presented to the cutter.

Figure 33 shows the relative positions of the boring head and the work at the completion of the cutting of the taper in the opening in the anterior wall.

Figure 34 shows the relative positions of the boring head and the work immediately prior to the cutting of the taper in the posterior wall. These positions may be called "conditioning" positions in that they are in preparation for the cutting of the taper in the posterior wall.

Figure 35 shows the relative positions of the boring head and the work when the work has been shifted to present the anterior face of the posterior wall to the boring head.

Figure 36 shows the relative positions of the work and the boring head when the taper has been cut in the opening in the posterior wall.

Figure 37 shows the relative positions of the boring head and the work when the boring head has been completely withdrawn from the work and both the boring head and the work have been restored to their original positions.

Figure 38 is a schematic side elevation showing a machine of modified construction in which the work unit is immovable and the boring bars are mounted on a movable carrier.

Figures 39 to 43 are sectional views in the same horizontal plane as Figures 15 and 16 through 20 and are arranged conjointly to constitute a graph (as indicated by the bracket) showing the relative positions of the work and the boring head in correspondence to the positions shown individually in Figures 16 to 20 respectively.

As an example of work selected for illustration the drawings show a section or unit U of a sectional boiler of a well known general type, the details here pertinent being sufficiently shown in Figures 1, 3, 5 and 15 through 20. In the assembled boiler units of the construction shown in the drawings are mounted in superposed relation and in each instance include a horizontal marginal water chamber C (Figure 5). The water chambers of adjoining units are in open communication with one another at any desired number of points. In the example shown the communication is at three symmetrically spaced points. For the purpose of establishing such communication each unit is formed with horizontal extensions K (Figure 1) which project radially outward and are circularly curved. These have parallel walls as best shown in Figures 15 through 20, one wall, designated

A, being anterior and the other, designated P, being posterior. In the molding of the units openings O are formed in the walls A and P and the machine of the invention bores tapers in these openings. In the assembly of the units to form the boiler the tapering openings are in alinement to provide continuous vertical water flow passages. The adjoining units are connected and their meeting faces sealed by thimbles of well known construction which is standard practice are fitted closely in the tapering walls of adjoining extensions K and have external surfaces which conform in taper to the tapers of the openings of the adjoining extensions. Since these thimbles are well known and form no part of the invention their illustration is deemed unnecessary.

In the example shown the openings O of one series are of substantially greater diameter than the openings of the other two series. The openings of greater diameter are provided in order that the water passage which they delimit may serve also as a casing for a water heating coil connected to the hot water supply line. As shown in Figure 3 the unit is positioned for the drilling of the tapers with the extensions K in which the openings of greater diameter are formed centrally located at the top and the extensions K in which the openings of less diameter are formed located at or near the lower side.

The machine includes three boring bars (using the term "bar" in the sense of an organization), one for each pair of alining openings. The boring bars are of structurally similar character and include boring heads which have the same movements similarly and simultaneously performed. The illustration in detail of one boring bar will therefore serve for all, the bar selected for illustration in Figure 15 being shown in relation to an extension K in which openings of less diameter are formed.

Each boring bar includes a driving element for the boring head. In the preferred embodiment (Figures 1 through 37) the driving element has a fixed mounting and the work has a sequence of rectilinear movements relatively to the driving element. Within its purview the invention comprehends relative movements of the work and the driving element by movements of the driving element relatively to the work as fixedly mounted (Figure 38). In either case the boring head has movements along an inclined path relatively both to the driving element and the work.

The frame of the machine (Figures 2, 4 and 5) includes a horizontal base 1 which carries fixed front and rear upright pedestals 2 and 3 positioned in parallel transverse planes.

The boring bars are indicated generally at 4 and as shown in Figure 15 in each instance have a driving element 5 in the form of a hollow shaft inclined along a central axis W. The shaft 5 carries front and rear end journals 6 and 7 respectively concentric with a major axis X which is preferably horizontal and is at all times coincident with the common axis XO of the alining openings O. The angle of the axes W and X determines the maximum permissive degree of the taper. The shaft 5 drives, and preferably encloses, a spindle 9 inclined along the axis W and mounted for longitudinal sliding movement relatively to the shaft 5. The axes W and X meet or intersect at a fixed point Z appropriately located behind the rear end face of the spindle 9. At its rear end, i. e., its end beyond the point Z, the spindle carries in driving relation a boring head 10 located beyond the rear journal 7 and in projecting relation to the shaft 5, the head 10, having a central horizontal axis Y which, prior to the boring operation, is coincident with the major axis C of the journals 6 and 7.

The driving connection between the boring head 10 and the spindle 9 is of detachable nature, thereby to enable the angular adjustment of the cutters carried by the boring head relatively to the spindle 9 or the substitution of a boring head of appropriate diameter for the particular openings in which tapers are to be bored. The inner end face of the boring head 10 is preferably in a vertical plane, that is to say a plane normal to the axis Y, and abuts the rear end face of the spindle 9. The driving connection of the head 10 is in the well known form of an extension 11 of annular cross section and reduced diameter, such extension being coaxial with the head 10 and having the usual slight degree of taper. The extension 11 fits comformably in a recess 12 open to the rear end face of the spindle 9, the annular wall of the recess having a taper corresponding to the taper of the extension 11. The head 10 is maintained in driven relation to the spindle 9 by a screw 13 fitted in a central axially extending opening in the head with its shank projecting beyond the extension 11, the projecting portion of the screw shank being engaged in a threaded recess 14 in countersunk and coaxial relation to the recess 12. When the screw 13 is tightened the extension 11 is drawn into tight wedging contact with the wall of the recess 12. When the screw 13 is backed off the boring head may be angularly adjusted relatively to the spindle 9, thereby to vary the extent of the radial movement of the cutters relatively to the axes X and XO consequent to the movement of the spindle 9 in the hole boring operation. It will be noted that the axes W and Y lie in a diametrical plane (which is assumed as the plane of the section of Figure 15) and that the axis Y is shiftable in this plane relatively to the axes X and XO as the spindle 9 is advanced in the hole boring operation. If, prior to the start of the operation, the cutters be positioned with their leading edges in this plane (as shown in the drawings) the cutters will have the maximum extent of radial movement relatively to the axes X and XO as the spindle 9 is advanced. However if the cutters by angular positional adjustment of the boring head 10 be originally positioned with their leading edges in a diametrical plane at an angle to the plane which includes the axes W and Y the extent of the radial movement of the cutters relatively to the axes X and XO as the spindle 9 is advanced will be decreased in proportion to the increase of angularity of the intersecting planes with the results (1) that a positional adjustment of the boring head 10 through an angle of 90° from the position assumed in the drawing will reduce the extent of the radial movement of the cutters relatively to the axes X and XO consequent to the advancing movement of the spindle from the maximum extent assumed in the drawings to zero, and (2) an angular positional adjustment of the boring head 10 beyond an angle of 90° and up to an angle of 180° will reverse the direction of the radial movement of the cutters relatively to the axes X and XO and the extent of such reversed radial movement will be progressively increased to a maximum at 180°.

The shaft 5 carries in fixed relation suitably spaced internal sleeves 8 which serve with a minimum of frictional contact for guiding the spindle 9 in its slidable movements. The shafts 5 are mounted in the pedestals 2 and 3 by means of ball bearings 17, the inner bearing rings being mounted fast on the journals 6 and 7. The shafts 5 of the two lower boring bars are directly mounted in bearing blocks 15 and 16 carried by the respective pedestals 2 and 3. Adjacent the pedestal 3 each shaft 5 is formed with an inwardly extending cylindrical face 18 concentric to the axis X. Each shaft 5 has an extension 19 beyond the journal 6 and concentric to the axis X to which a driving pulley 20 is connected by screws 21, the pulley being directly mounted upon an adapter clamped between it and the end face of the extension 19.

The spindle 9 is driven from the shaft 5 by means of a suitable key 23 mounted for longitudinal movement in either direction relatively to the shaft 5, the key according to its direction of longitudinal movement effecting the advancing or retractile movements of the spindle. The key 23 has a secure fit in a diametrical opening 24

formed in the spindle 9. To insure this the key is made in two parts 25 and 26 having cooperating wedge faces. These faces are formed to delimit an opening for a diametrically arranged screw 27, a part 28 of the opening wholly within the key part 25 being threaded for cooperation with the screw. The function of the screw 27 is relatively to expand the key parts into strong frictional contact with the wall of the opening 24. The end portions of the key parts 25 and 26 project suitably beyond the spindle 9 and are located in longitudinal slots 29 corresponding in width to the diameter of the key and formed in the shaft 5 between its cylindrical faces, thereby to couple the spindle 9 in driven and slidably mounted relation to the shaft 5. The key 23 is accordingly movable in either direction, lengthwise of the shaft, in the slots 29, its movement being effected by a collar 30 rotatable with the shaft 5 and slidably mounted upon its face 18. The collar 30 is provided with diametrically opposite openings 31 and 32, the opening 31 giving access to the head of the screw 27 and the opening 32 accommodating with a suitable loose but driving fit that portion of the key part 25 which projects beyond the face 18. The movement of the collar 30 along the face 18 is transmitted by the key 23 to the spindle 9.

The boring head 10 carries radially projecting cutters arranged in diametrically opposite relation and preferably provided in pairs, the cutters of a pair being in longitudinal alinement and being roughing and finishing cutters respectively. The cutters of one pair form the taper in the opening of the wall A and the cutters of the second pair form the taper in the opening of the wall P. According to the angular positional adjustment of the boring head 10 relatively to the spindle 9 the opposite tapers may be cut in either direction and in various degrees of angularity less than maximum.

Figures 15 through 20 assume that the tapers will be cut with their permissive maximum angularity and with their minimum diameters in mean relation. The cutters are arranged in "first" and "second" pairs, these terms being used with reference to the sequence in which the pairs of cutters operate. In Figures 15 through 20 the first cutters 33 and 34 cut the taper of the hole in wall A and the second cutters 35 and 36 cut the taper of the hole in the wall P. The finishing cutter of each pair follows the roughing cutter and projects a few thousandths of an inch, e. g. .015, beyond it. In the example assumed by Figures 15 through 20 the cutters 33 and 34 have a slightly greater projection from the periphery of the head 10 than the cutters 35 and 36, i. e., of the order of .019 inch. This greater degree of projection of the cutters 33 and 34 is provided for the reason that while they are cutting the taper of the hole in the wall A the cutters 35 and 36 must move through the hole without contact with its wall.

In the example shown in Figures 15 through 20, as the boring head 10 is advanced the cutters 33 and 34 approach the major axis X and the cutters 35 and 36 move away from it. Since the cutters 33 and 34 have a greater degree of projection from the boring head than the cutters 35 and 36 they are operative to cut the taper in the opening of the anterior wall. These figures assume that in any position of the boring head 10 consequent to the movement of the spindle 9 along its axis W the pairs of cutters are respectively at their permissible maximum and minimum distances radially from the axis X. By the angular adjustment of the boring head in either direction about its axis Y through an angle of 90° from the position assumed in Figures 15 through 20 the extent of the radial movement of the cutters relatively to the axes X and XO as the boring head is advanced may be progressively varied. In this manner the angularity of the tapers in the two walls may be predeterminately decreased from the permissive maximum degree. With reference to the position of the boring head shown in Figures 15 through 20 its angular adjustment through an angle of 90° progressively reduces the extent of radial movement of the cutters 33 and 34 relatively to the axes X and XO as the boring head is advanced, whereby the angle of the taper of the opening in the wall A may be progressively reduced from maximum to zero at 90°. When the angular adjustment of the boring head 10 about its axis Y is to be continued beyond 90° from the position assumed in Figures 15 through 20 and up to 180° the taper is cut in the wall A by the cutters 35 and 36 and in the wall P by the cutters 33 and 34. In such instances the cutters 35 and 36 are positioned to project radially through an appropriately greater distance from the periphery of the boring head than the cutters 33 and 34 and the directions of the tapers are reversed from the directions assumed in Figures 15 through 20.

A separate electric motor is preferably provided for each shaft 5. The motor 37 for the upper boring bar (Figures 1, 2 and 5 being considered) is mounted on a bracket 38 secured by bolts to the flat upper edge faces of the pedestals 2 and 3 and its shaft carries a pulley 39 connected by a belt or belts 40 to the pulley 20 of the shaft 5 of the upper boring bar. The motors 41 for the shafts 5 of the two lower boring bars are mounted on laterally projecting brackets 42, each formed with an attachment plate 43 secured by bolts to the flat inclined side edge faces of the pedestal 2, the shafts of the motors 41 being similarly belt geared to the respective pulleys 20 of the shafts 5 of the two lower boring bars.

The work U is secured in upright position beyond the boring bars in a plane normal to the axis X. The supports for the work unit and the boring bars may be regarded as companion elements having rectilinear relative movements, one element being fixed and the other being movable. In the preferred embodiment the unit U is mounted upon a carrier 44 (Figures 1, 2, 3 and 5) which consists of a base 45 and a frame 46 mounted upon it in upright relation in a transverse plane. The frame base 1 is provided along its sides with projecting flanges 47. The carrier base 45 has depending side walls 48 to the lower faces of which securing strips 49 are attached, these engaging under the flanges 47 and preventing any upward or canting displacement of the carrier. The frame base 1 is preferably formed in its upper face with a longitudinal way 50 having sides which flare upward and the carrier base 45 is fashioned with projections 51 on its under face which are inclined conformably to and bear against the sides of the way 50. The frame 46 conforms in general outline to the work and has an upward extension 52 to accommodate work clamping means. This preferably includes a vertically movable cylinder 53 hydraulically operated in relation to a fixed piston 54 provided at the lower end of a stem 55. The piston carrying stem 55 projects through the upper head of the cylinder, is pendent from the bow or cross piece at the upper end of the extension 52, and has passages for the flow of the operating fluid into and from the spaces at each side of the piston. The cylinder 53 is formed with vertical diametrically opposed external flanges 56 which bear against the vertical side pieces of the extension 52 and carry work engaging elements 57. These are shown in detail in Figure 7 and are secured by screws 58 to the lower ends of the flanges 56. The elements 57 have their inner faces formed with recesses 59 which accommodate and center the work unit extension K. Other work engaging elements 60 are arranged on the carrier base 45 and are secured by screws 61 to the side bars of the frame 46. The elements 60 engage the two lower extensions K of the work unit U and have their inner faces formed with recesses 62 which similarly accommodate and center these extensions. It will be apparent that when the cylinder 53 is moved to its lower position and held in such position under the pressure of the operating fluid the elements 57 and 60 will engage the annular walls of the extensions K and will cooperate in securely holding the work unit within the frame of the carrier in a position in which its openings O are, and

at all times remain, concentric with extensions of the axes X. The flow of the operating fluid to and from the cylinder 53 is controlled by a manually operated valve 63 (Figure 2).

The carrier 44 is moved rectilinearly in either direction and through steps of appropriate length by a fluid motor 64 (Figures 5 and 6) having a fixed piston 65 mounted on a stem 66 and a movable cylinder 67. The stem 66 is secured to a lug 68 mounted on the frame base 1 and the cylinder 67 carries a centrally located axially projecting post 69 tapped into an opening in the inner edge face of the carrier base 45. The piston carrying stem 66 is similar in construction to the stem of the work clamping means 55. The cylinder 67 is preferably slidably mounted in an opening in the pedestal 3, specifically in a block 70 provided on the frame base and located within an opening 71 formed in the pedestal 3 to reduce weight. The slidable movements of the spindles 9 are effected by a vertical spider 72 mounted in a transverse plane (Figures 4 and 5). In the example shown the spider 72 is of generally inverted Y shape and is formed with three arms 73, each serving for the operation of one of the spindles. The spider 72 is prevented from turning about a horizontal axis by a guide rod 74 extending between the pedestals 2 and 3 and passing through an opening in the upper arm 73 of the spider. The spider 72 directly effects the movements of the collars 30. For this purpose each collar 30 is formed with a circumscribing annular flange 75 in a plane normal to the axis X and each arm 73 carries at its outer end a pair of antifriction rollers 76 tracking upon opposite side faces of the flange of the corresponding collar. The spider 72 is operated by a fluid motor 77 which has a fixed piston 78 and a movable cylinder 79. The pedestal 2 carries a horizontally projecting bracket 80 and the stem 81 of the piston 78, which is similar in construction to the stem 66, is fixed to, and projects horizontally from the end wall of the bracket 80. The spider 72 has a central opening in which the cylinder 79 fits, the spider being clamped in position between an annular flange 82 on the cylinder and a collar 83 threaded upon the end of the cylinder. The pedestal 3 serves as a support and guide for the cylinder 79 and is formed with an opening 84 within which the cylinder 79 has its sliding movement. The bracket 80 is conveniently in cylindrical form, is attached by a screw 85 to the pedestal 2, and has an opening 86 which gives access to the nut 87 by which the piston stem 81 is secured.

In the preferred embodiment shown the work U has four vertical planar positions indicated respectively in Figures 15, 16, 17 and 18 and also respectively in Figures 43, 39, 40 and 41 as B, C, D and E and the boring head has four positions indicated respectively in Figures 15, 17, 18 and 19 as F, G, H and I and also respectively in Figures 43, 40, 41 and 42.

Figure 15 shows the work and the boring head in relatively inactive positions. In this figure the work unit U is in position B and is suitably spaced back of the boring head 10 which is in position F.

The first step in the operation of the machine is shown in Figures 16 and 39. In this step, while the boring head remains stationary in position F, the work is advanced from position B (Figure 15) to position C in which the anterior face of the anterior wall A is in a plane substantially coincident with the vertical plane of the leading or active edge of the cutter 33 and the wall of the anterior opening O is operatively presented to the cutters 33 and 34. With the work remaining in position C the boring head is advanced in a direction opposite to that of the advancing movement of the work to position G (indicated in broken lines) whereby the cutters 33 and 34 are fed through the anterior opening O and cut the required taper of its wall. The tapering cut of the anterior opening O is sufficiently shown in Figure 17 by resort to the expedient of dot and dash extension lines.

The second step of movement of the work is shown in Figure 17. In this step, while the boring head remains stationary in position G, the work is advanced in the same direction as before to position D in which the anterior face of the posterior wall P is in a plane substanially coincident with the vertical plane of the leading or active edge of the cutter 35 and the wall of the posterior opening O is operatively presented to the cutters 35 and 36. With the work remaining in position D the boring head is advanced in a direction opposite to that of the advancing movement of the work to position H (indicated in broken lines) whereby the cutters 35 and 36 are fed through the posterior opening O and cut the required taper of its wall. The tapering cut of the posterior opening O is shown in Figure 17 by resort to the expedient of dot and dash extension lines.

After the tapers have been cut in the anterior and posterior openings as above described, the work is moved to positions which enable the return of the boring head 10 to its initial or inactive position shown in Figure 15. These movements of the work and of the boring head are shown in the order of their succession in Figures 18, 19 and 20 (in which the final position of the boring head is shown in broken lines).

With the boring head remaining in its position H as shown in Figures 18 and 41 the work is then advanced in the same direction as before through its third step of movement (shown in broken lines in Figure 41) to position E shown in full lines in Figures 19 and 42. This position of the work permits the boring head to be moved in the direction opposite to that of its previous movements, i. e., retractile direction through a first step in its withdrawal from the work. This step is shown in Figures 19 and 42 and involves the movement of the boring head to position I while the work remains in position E. The advance of the work to position E insures that the cutters may be withdrawn from the posterior opening O without contact with its wall. In position I of the boring head the cutters 36 and 34 have been completely withdrawn from the posterior opening O while the cutters 35 and 33 remain in such opening but without contact with its wall.

With the boring head remaining in position I the next step in its withdrawal from the work is the retractile movement of the work (as shown in broken lines in Figure 42) from position E back to its initial position B. These relative positions of the work unit and the boring head are shown in Figures 20 and 43. At this stage the cutters 35 and 33 are located behind the anterior wall A of the work and the cutters 36 and 34 are located within the anterior opening O but without contact with its wall.

After the work has been returned to its initial position B and while it remains in such position the boring head is moved through the second and final step in its withdrawal. In this step the boring head is moved from position I back to its initial or inactive position F (indicated in broken lines in Figures 20 and 43), the cutters 35 and 33 being withdrawn from the anterior opening O without contact with its wall. The work and the boring head at such time are in the relative positions shown in Figure 15. At this stage the work is removed from the carrier 44 and a new unit U having holes in which tapers are to be cut is mounted in the carrier, such a new unit being assumed in Figure 15. The cycle of operations is thereupon repeated.

As will appear from the foregoing description in the operation of the machine the boring head and the work unit each have a cycle of step-by-step movements, these being coordinated and constituting a series of operative steps in each of which the boring head and the work unit are in cooperative relation.

By way of recapitulation these steps are graphically illustrated in Figures 13 and 14 which are to be read together, Figure 13 illustrating the cycle of movements of the boring head and Figure 14 illustrating the cycle of movements of the work unit.

Figures 13 and 14 are to be considered in relation to the previous description of the several steps as based upon the disclosures of Figures 15 through 20 and Figures 39 through 43. With the boring head in position F and the work unit in which tapers are to be cut in position B (Figure 15) the first step S1 as shown by the graph of Figure 14 is the movement of the work unit from position B to position C (Figures 16 and 39). With the work unit in position C the second step S2 as shown by the graph of Figure 13 is the cutter feeding movement of the boring head from position F to position G (Figures 16 and 39 and 17 and 40) in which the cutters 33 and 34 form the taper of the wall of the anterior opening O. With the boring head in position G the third step S3 as shown by the graph of Figure 14 is the movement of the work unit form position C to position D (Figures 17 and 40). With the work unit in position D the fourth step S4 as shown by the graph of Figure 13 is the cutter feeding movement of the boring head from position G to position H (broken lines Figure 17) in which the cutters 35 and 36 form the taper of the wall of the posterior opening O. With the boring head in position H the fifth step S5 as shown by the graph of Figure 14 is the movement of the work unit from position D to position E (Figures 18 and 41). With the work unit in position E the sixth step S6 as shown by the graph of Figure 13 is the retractile movement of the boring head from position H to position I (Figures 19 and 42). With the boring head in position I the seventh step S7 as shown by the graph of Figure 14 is the movement of the work unit from position E to position B (Figures 20 and 43). With the work unit in position B the eighth step S8 as shown by the graph of Figure 13 is the movement of the boring head from position I to position F (Figure 15 and broken lines of Figures 20 and 43). At this stage the work unit in which tapers have been cut is removed and a work unit in which tapers are to be cut is positioned and secured upon the carrier 44.

In respect to the foregoing description of the operative steps of movement of the parts it will be seen that the axis W of the shaft 5 and spindle 9 rotates about the major axis X of the journals 6 and 7 (Figure 21) and as the spindle 9 is advanced in the operation of the machine the axis W generates opposed cones which have their apices at the point Z. With the boring head and the work unit in their inactive positions as shown in Figure 15 the horizontal axis Y of the boring head is alined or coincident with the axis X of the journals 6 and 7 (Figure 22). When the boring head is moved through the steps S2 and S4 (Figures 16 and 18) its axis Y moves away from the axis X but is maintained in parallel relation to it. This will be apparent from a comparison of Figures 22 and 23.

From the foregoing description it will be apparent that the taper in the anterior wall is formed by the pair of cutters which have the greater degree of projection from the periphery of the boring head; that when the taper is to be cut with its maximum diameters in extreme relation and its minimum diameters in mean relation, the cutting of the taper is produced by the cutters which move radially toward the axis X; and that when the taper is to be cut with its minimum diameters in extreme relation and its maximum diameters in mean relation the cutting of the taper is produced by the cutters which move away from the axis X.

Referring in detail to the cutting of the taper with its maximum diameters in extreme relation and its minimum diameters in mean relation as shown in Figures 15 through 20 and 39 through 43:

In the movement of the boring head through the step S2 the taper is cut in the wall of the interior opening O by the cutters 33 and 34 with its maximum and minimum diameters respectively at the outer and inner faces of the anterior wall A. This is for the reason that while the axis Y of the borinng head is being moved away from the axis X the cutters 33 and 34 are being progressively moved radially nearer to the axis X, thereby cutting spirals of progressively diminishing diameters and producing the tapering cut which is best illustrated by the extension lines of Figure 17. When the boring head is moved through the step S4 (Figure 17) its axis Y continues, in parallel relation, to move away from the axis X. In the movement of the boring head through the step S4 the taper is cut in the wall of the posterior opening O by the cutters 35 and 36, this taper having its minimum and maximum diameters respectively at the inner and outer faces of the posterior wall P. This is for the reason that during the movement of the boring head through the step S4 the cutters 35 and 36 at the same time are being progressively moved radially further from the axis X, thereby cutting spirals of progressively increasing diameters and producing the tapering cut which is best illustrated by the extension lines of Figure 18.

The piston stems 55, 66 and 81 are of similar construction, the details being shown in Figure 24, a sectional view of the motor 64. The piston stem consists of an inner tubular part 88 and an enclosing outer tubular part 89, these parts being connected to the piston 65 and to the supporting lug 68. The part 88 has an axial passage 90 which extends between its ends and is open to the cylinder space at the front of the piston, i. e. the cylinder space at the right of the piston, Figure 24 being considered. The part 88 has end portions 91 of greater diameter than its body portion, these being fitted in sealed relation in the part 89. The reduction in diameter of the body portion of the part 88 provides a channel 92 of annular cross section.

The liquid flow paths are the same for the several piston stems. The passages 90 of the piston stems 66 and 81 are connected in each instance externally of the cylinder to a liquid flow tube 93. The passage 90 of the piston stem 55 is similarly connected to a corresponding liquid flow tube 93'. The operating liquid flows in either direction through the passages 90 and the connected liquid flow tubes, the flow of the liquid into the cylinder space at either side of the piston effecting the corresponding movement of the cylinder and the flow of the liquid from that space enabling the movement of the cylinder in the opposite direction. The channels 92 of the piston stems 66 and 81 are connected in each instance externally of the cylinder to a liquid flow tube 94. The channel 92 of the piston stem 55 is similarly connected to a corresponding liquid flow tube 94'. The channel 92 communicates with the cylinder space behind the piston through an opening 95 formed in the part 89 adjacent the piston. The operating liquid flows in either direction through the channels 92 and the connected liquid flow tubes into the cylinder space at either side of the piston effecting a corresponding movement of the cylinder and the flow of the liquid from that space enabling the movement of the cylinder in the opposite direction.

The flow of the liquid is effected by a pump of any suitable construction, illustration of which is deemed unnecessary. The control of the flow of the liquid is effected by valves, severally provided in operative relation to the liquid flow tubes connected to each piston stem.

The manual valve 63, as above pointed out, controls the flow of the liquid in relation to the piston stem 55. The flow of the liquid in relation to the piston stems 66 and 81 is controlled by automatically operated valves 96 and 96*a* respectively. Figure 11 shows the valve 96, the valve 96*a* being similar in construction and operation.

The valve 96 includes a valve casing 97 and an enclosed valve body 98. The casing 97 and valve body 98 are preferably of cylindrical form, the valve body having a close fit within the chamber of the casing 97 and being slidable between its end walls.

The valve casing is provided adjacent its respective ends with liquid inlet nipples 99 and 100 and between these with a liquid return nipple 101. The liquid supply line

(not shown) from the pump is connected to liquid flow pipes (Figure 5) 102 and 103 and the liquid return line (not shown) to the pump is connected to a liquid return pipe 104. The nipples 99 of the valves 96 and 96a communicate with a supply branch 105 (Figure 6) and the nipples 100 similarly communicate with a supply branch 106. The liquid flow pipes 102 and 103 are connected respectively to the branches 105 and 106. The nipples 101 of the valves 96 and 96a are connected by a branch 107 to which the return pipe 104 is connected. Each valve casing 97 is also provided with nipples 108 and 109 in angular relation to the nipples 99, 100, 101. The liquid flow tubes 93 and 94 are connected to the nipples 108 and 109 respectively. The valve body 98 is formed with circumferential channels 110 and 111. The valve casing 97 is formed with a longitudinal passage 112 at all times in open communication at an intermediate point with the return nipple 101, the passage 112 having terminal branches 113 and 114 which are open to the inner face of the valve casing chamber. The valve casing 97 is also formed with longitudinal passages 115 and 116 which respectively are at all times in communication with the nipples 108 and 109. The passage 115 has terminal branches 117 and 118 and the passage 116 has similar terminal branches 119 and 120, the several terminal branches being open to the inner face of the valve casing chamber.

The valve body 98 has operative left and right positions, Figure 11 being considered. The corresponding motor 64 is shown in Figure 24. In its position at the right, as indicated by broken lines in Figure 11, the channel 110 registers with the nipple 100 and the branch 117, and the channel 111 simultaneously registers with the branches 114 and 119, the valve body closing the branches 113, 118 and the nipple 109 and the branch 120. In this position of the valve body the flow of liquid is through the nipple 100, the channel 110, the branch 117, the nipple 108 and the pipe 93 and the axial passage 90 of the piston stem 66 to the cylinder space in front of the piston 65 whereby pressure is applied to the right end head of the cylinder 67 to move it to the right, Figures 5 and 24 being considered. At the same time, the movement of the cylinder 67 to the right thereby being made possible, liquid flows from the cylinder space behind the piston 65 through the opening 95, the channel 92, the tube 94, the nipple 109, the branch 119, the channel 111, the branch 114, the passage 112, the nipple 101 and the return tube 104 to the liquid return line which leads to the low pressure side of the pump. In the position of the valve body 98 at the left as shown in full lines the channel 111 registers with the nipple 99 and the branch 120 and the channel 110 simultaneously register with the branches 113 and 118, the valve body closing the branches 114 and 119, the nipple 100 and the branch 117. In this position of the valve body the flow of liquid is through the nipple 99, the channel 111, the branch 120, the nipple 109, the tube 94, the channel 92 and the opening 95 to the cylinder space behind the piston 65 whereby pressure is applied to the left end head of the cylinder 67 to move it to the left. At the same time, the movement of the cylinder 67 to the left thereby being made possible, liquid flows from the cylinder space in front of the piston 65 through the passage 90, the tube 93, the nipple 108, the branch 115, the channel 110, the branch 113, the passage 112, the nipple 101 and the return tube 104 to the liquid return line which leads to the low pressure side of the pump.

The liquid flow circuits of the valve 96a and the associated motor 77 are similar to those of the valve 96 and the associated motor 64.

In the case of the motor 77 the movements of the cylinder 79 to effect the operations of the boring heads are to the right, Figure 5 being considered, and the operating fluid for such movements is delivered through the flow tube 93 and the passage 90 to the cylinder space in front of the piston 78. It is preferable that provision be made for regulating the rate of flow of the operating fluid and the flow tube 93 therefore is provided with a shunt 121 (Figure 6) in which is fitted a manually adjustable regulating valve 122. The tube 93 carries a check valve 123 between the points of connection of the shunt 121 which permits the free retrograde flow of the operating fluid through the tube 93 but compels the flow of the operating fluid through the shunt 121 in connection with its delivery to the cylinder space in front of the piston 78.

The valve body 98, in addition to the extreme or left and right operative positions which establish the liquid flow circuits above described, has an intermediate or neutral position sufficiently indicated in Figure 11 by the showing of the channels 110 and 111 in broken lines coincident with transverse planes N. In this position the valve body cuts off the communication with the channels 110 and 111 of the nipples 99, 100, 108 and 109 and the branches 113, 114, 117, 118, 119 and 120 and thereby functions as a barrier, rendering the liquid flow circuits inoperative and causing the parts controlled by the particular fluid motor 96 or 96a as the case may be, namely the work unit U and the boring heads 10, to remain in the positions to which they were moved in consequence of the immediately preceding operative movement of the valve body. The duration of the valve body in either of its operative positions determines the extent of movement of the controlled parts, i. e. the work unit and the boring heads, and its duration in the neutral position determines the periods of rest of the controlled parts. Accordingly each valve body 98 is under the control of a suitable governing mechanism to be later described. Thereby the periods of movements and rest of the controlled parts are coordinated, all as above described and sufficiently shown in the complementary graphs of Figures 13 and 14.

The manually operated valve 63 for controlling the flow of the operating liquid with respect to the work clamping means, that is to say through the liquid flow tubes 93' and 94', may be of any suitable construction, the details of one such construction being shown in Figures 25, 26 and 27. As shown in these figures the valve 63 is of the turning plug type and comprises a casing 124 and an enclosed rotatably mounted valve body 125, one of the mounting trunnions of which carries an operating handle 126. The casing 124 is formed with upper and lower nipples 127 and 128 preferably located in the central transverse plane and connected to the respective flow tubes 93' and 94'. At its opposite side the casing 124 is formed with nipples 129 and 130 preferably located at opposite sides of the central transverse plane. A liquid supply tube 131 leading from the high pressure side of the pump is connected to the nipple 129 and a liquid return tube 132 leading to the low pressure side of the pump is connected to the nipple 130. The valve body 125 is formed with a passage 133 which is preferably located in a central longitudinal plane and at one end, according to the position of the valve body, directly communicates with either of the nipples 127 or 128, its opposite end communicating at a central point with a peripheral recess 134 which also constitutes a liquid flow passage and is at all times in communication with the nipple 129 to which the supply tube 131 is connected. Since the nipples 127 and 128 are in a central transverse plane of the valve casing 124 and the nipple 129 is at one side of such plane the passage 133 is laterally inclined as shown in Figure 25. For return flow purposes the valve body 125 is also formed with passages 135, 136 and 137, these being radially directed and in mutual communication at a point along the central axis of the valve body. In one operative position of the valve body as shown in Figure 27 the passage 135 (which extends to the periphery of the valve body) communicates with the nipple 128 and the passage 136 is in a neutral position as shown in broken lines at 136a in Figure 26. In the second operative position of the valve body the passage 136 (which also extends to the periphery of the valve body) communicates

with the nipple 127 and the passage 135 is in a neutral position as shown in broken lines at 135*a*. The passage 137 communicates at a central point with a peripheral recess 138 which also constitutes a liquid flow passage and is at all times in communication with the nipple 130 to which the return tube 132 is connected. Since the nipple 130 is at one side of the transverse plane in which the nipples 127 and 128 are located the passages 135, 136 and 137 are in a common plane laterally inclined as shown in Figure 25 in a direction opposite to the inclination of the passage 133.

In Figure 3 it is assumed that the valve body is positioned for the delivery of the operating fluid to the cylinder space below the piston 54, this position being shown in Figures 26 and 27. With the valve body so positioned the operating liquid flows from the pipe 131 through the recess 134, the passage 133, nipple 127, tube 93' and passage 90 into the cylinder space below the piston 54, thereby to move the cylinder downward and effect the clamping action. This downward movement of the cylinder is permitted by the escape of the operating liquid from the cylinder space above the piston 54, the return flow of the liquid being through the opening 95, the channel 92, the tube 94', the nipple 128, the passages 135 and 137, the recess 138, the nipple 130 and the return tube 132 to the low pressure side of the pump.

Any suitable means may be provided for limiting the movement of the handle 126 into either of the positions required by the vlave body 125. The positions of the valve handle 126 shown respectively in full lines and in broken lines 126*a*, Figures 2, 26 and 27 may be called "clockwise" and "counterclockwise."

When the cylinder 53 is to be moved to diseangage the clamping elements and permit the removal of the work piece from its carrier the handle 126 is moved to its counterclockwise position. Thereupon the passage 133 is brought into communication with the nipple 128, the passage 136 is brought into communication with the nipple 127 and the passage 135 is brought into its neutral position 135*a*.

With the valve body so positioned the operating liquid flows from the pipe 131 through the recess 134, the passage 133, nipple 128, tube 94', channel 92 and opening 95 into the cylinder space above the piston 54, thereby to move the cylinder upward with the resultant release of the work unit. This upward movement of the cylinder is permitted by the escape of the operating liquid from the cylinder space below the piston, the return flow of the liquid being through the passage 90, tube 93', nipple 127, passages 136 and 137, passage 138, nipple 130 and return tube 132 to the low pressure side of the pump. When the elements 57 have been sufficiently disengaged consequent to the movement of the handle 126 to its counterclockwise position the work unit U is removed from its carrier 44.

The movements of the valve bodies 98 of the valves 96 and 96*a* are preferably effected by double acting solenoids 139 and 139*a* respectively (Figures 6 and 28). Since such solenoids are of well known construction illustration of their details is not required. It will be sufficient to point out that each includes opposed windings 142 and 143 and any usual means for normally holding their armatures 140 in a central position which is also a neutral position. The armature stems 141 extend through openings in the adjacent heads of the corresponding valve casings 97 and are connected to the valve bodies.

When the boring heads and the work unit are in the relative positions shown in Figure 15 the armatures of both solenoids are in neutral position, these positions being assumed in Figures 6 and 28. In these positions the armatures hold the valve bodies 98 in their neutral positions. The windings 142 and 143 are used to effect the movement of the valve bodies 98 from their neutral positions to their extreme positions at the left and right respectively (Figure 11 being considered).

The energization of the windings 142 and 143 of the two solenoids is controlled by a cyclically movable governing element which is preferably in the form of a rotatable contact carrying disc 144 (Figures 6, 12 and 28) mounted detachably but in driven relation on the shaft of an electric motor 145, one complete revolution of the element 144 corresponding to a complete cycle of operation of the machine as indicated by the complementary graphs of Figures 13 and 14.

The contact carrying disc 144 is composed of suitable insulating material and is shown in sufficient detail in Figure 12. On one of its flat faces it is provided with contacts for carrying out the steps S1 to S8 illustrated in the graphs of Figures 13 and 14. The contacts are of arcuate form and are indicated in their relation to the several steps by the index letter *a*, hence being designated as S1*a*, S2*a*, S3*a*, S4*a*, S5*a*, S6*a*, S7*a*, and S8*a*. The movable contacts S1*a* through S8*a* are severally in cooperation with stationary contacts 146, 147, 148 and 149 located at different distances radially from the center of the disc 144 and preferably arranged in a radial line. The contacts S1*a*, S3*a* and S5*a* engage the stationary contact 146. The contact S7*a* engages the stationary contact 147. The contacts S2*a* and S4*a* engage the stationary contact 148, and the contacts S6*a* and S8*a* engage the stationary contact 149. Hence the contacts S1*a* through S8*a* are variously arranged along concentric circles which correspond severally in radial location to the radial location of the cooperating stationary contacts.

The graph of Figure 14 shows the movements of the work unit, these movements being the steps S1, S3, S5 and S7. The advancing movements of the work unit are effected by the engagement of the movable contacts S1*a*, S3*a*, S5*a* with the stationary contact 146 and the retractile movement of the work unit is effected by the engagement of the movable contact S7*a* with the stationary contact 147. The annular extent of each of the contacts S1*a*, S3*a*, S5*a* and S7*a* determines the period of their engagement with the companion stationary contact and hence dictates the duration of the valve body in the corresponding position and thereby determines the extent of movement of the work unit. When each of the several contacts S1*a*, S3*a*, S5*a* and S7*a* has passed beyond, i. e. disengaged, the stationary contact with which it cooperates the solenoid armature is returned by the solenoid mechanism to its neutral position and the work unit remains in the position to which it has been moved for a period dictated by the spacing between the adjacent contacts of the annular series S1*a*, S3*a*, S5*a* and S7*a*. In detail: The contact S1*a* effects the movement of the work unit from the position of Figure 15 to the position of Figures 16 and 39 (step S1), the valve body 98 of the valve 96 being moved to its operative position at the left, Figure 11 being considered, and when the contact S1*a* passes beyond the corresponding stationary contact 146 the armature of the solenoid 139 is shifted back to its neutral position, thereby moving the valve body 98 of the valve 96 back to its neutral position. The work unit remains in its position shown in Figures 16 and 39 for a period corresponding to the spacing of the contacts S1*a* and S3*a* and during this period the boring heads 10 are moved through the step S2 (Figure 13). Upon the completion of step S2 of the boring heads the movable contact S3*a* engages the stationary contact 146 with the result of the work unit being similarly moved through step S3 (Figure 14) to the position shown in Figure 17. When the contact S3*a* passes beyond the contact 146 the armature of the solenoid 139 is again shifted back to its neutral position, thereby moving the valve body 98 of the valve 96 to its neutral position with the result that the work unit remains in its position shown in Figures 17 and 40 for a period corresponding to the spacing of the contacts S3*a* and S5*a* and during this period the boring heads 10

are moved through step S4. Upon the completion of the step S4 of the boring heads the movable contact S5*a* engages the stationary contact 146 with the result of the work unit being similarly moved through the step S5 to the position shown in Figures 18 and 41. When the contact S5*a* passes beyond the contact 146 the armature of the solenoid 139 is again shifted back to its neutral position, thereby moving the valve body 98 of the valve 96 to its neutral position with the result that the work unit remains in its position shown in Figures 18 and 41 for a period corresponding to the spacing of the contacts S5*a* and S7*a* and during this period the boring heads 10 are moved through the step S6, their initial retractile step which is from their positions shown in Figures 18 and 41 to their positions shown in Figures 19 and 42. Upon the completion of the step S6 of the boring heads the movable contact S7*a* engages the stationary contact 147, the valve body 98 of the valve 96 being then moved to its operative position at the right with the result that the work is moved through its retractile step to the position shown in Figure 20. Thereupon the boring heads are moved through the step S8, their final retractile step, to their positions shown in broken lines in Figure 20. The contact 146 is connected by a wire 150 (Figure 28) to the winding 142 of the solenoid 139 and the contact 147 is connected by a wire 151 to the winding 143 of the solenoid 139. The energization of the winding 142 of the solenoid 139 effects the advancing movements of the work unit, that is to say movements to the left through the steps S1, S3 and S5, Figure 5 being considered, and the energization of the winding 143 of the solenoid 139 effects the retractile movement of the work unit, a movement to the right through the step S7, all as above described. The advancing movements of the boring heads are to the right, Figure 5 being considered, and are effected by the engagement of the movable contacts S2*a* and S4*a* with the stationary contact 148 and the retractile movements of the boring head are to the left and are effected by the engagement of the movable contacts S6*a* and S8*a* with the stationary contact 149. The energization of the winding 143 of the solenoid 139*a* effects the movement of the valve body 98 of the valve 96*a* to the left (Figure 11 being considered) with resultant advancing movements of the boring heads, that is to say movements to the right and the energization of the winding 142 of the solenoid 139*a* effects the movements of the valve body 98 of the valve 96*a* to the left with resultant retractile movements of the boring heads. The contact 148 is connected to the winding 143 of the solenoid 139*a* by a wire 152 and the contact 149 is connected to the winding 142 of the solenoid 139*a* by a wire 153. When the several contacts S2*a*, S4*a*, S6*a* and S8*a* pass beyond their corresponding stationary contacts the mechanism of the solenoid 139*a* returns the armature to the neutral position with resultant movement of the valve body 98 of the valve 96*a* to its neutral position, the boring heads thereupon remaining in the positions to which they were previously moved.

The contact carrying disc 144 is provided with a peripheral contact 154. A current supply line 155 is connected at a neutral point to all of the windings of both solenoids. A current return line 156 has a constant brush contact with the peripheral contact 154 of the carrier 144. The movable contacts S1*a* through S8*a* are also connected to the peripheral contact 154 of the carrier 144. The circuits for the energization of the solenoids may be traced as follows with reference to Figure 28: When any of the movable contacts S1*a*, S3*a* and S5*a* are in engagement with the companion stationary contact 146 the flow of current is from the supply line 155 through the winding 142 of the solenoid 139, the wire 150, the contact 146, the movable contact engaged with the contact 146, the peripheral contact 154 and the return line 156. When the movable contact S7*a* is engaged with the companion stationary contact 147 the flow of current is from the supply line 155 through the winding 143 of the solenoid 139, the wire 151, the contact 147, the peripheral contact 154 and the return line 156. When either of the movable contacts S2*a* and S4*a* is in engagement with the companion stationary contact 148 the flow of current is from the supply line 155 through the winding 143 of the solenoid 139*a*, the wire 152, the contact 148, the movable contact engaged with the contact 148, the peripheral contact 154 and the return line 156. When either of the movable contacts S6*a* and S8*a* is engaged with the companion stationary contact 149 the flow of current is from the supply line 155 through the winding 142 of the solenoid 139*a*, the wire 153, the contact 149, the movable contact engaged with the contact 149, and the return line 156.

When the step S8*a* is completed the supply of current to the motor 145 is automatically cut off. At this time the boring head is in the position relatively to the processed work unit which is shown in broken lines in Figure 20. It is at this stage that the processed work unit is removed and an unprocessed work unit substituted. Thereupon a manual switch is operated to close a circuit for initiating the operation of the motor, the contact disc 144 thereafter establishing the motor operating circuit, the cycle being completed as previously described.

The operating circuit for the motor 145 includes a contact 157 of circular outline mounted on the disc 144 at the side opposite the movable contacts S1*a* through S8*a*. The contact 157 does not extend through a complete circle but is formed to provide a gap 158 (Figure 12). The contact 157 cooperates with spaced stationary contacts 159 and 160. During the operation of the machine the contact 157 engages both of the stationary contacts as shown schematically in Figure 28. The motor operating circuit includes a feed wire 161 branching from the line wire 155 and connected to one pole. The other pole of the motor is connected by a wire 162 to the stationary contact 159. The stationary contact 160 is connected by a wire 163 to the return line 156. With the machine in operation the motor circuit may be traced as follows: Through the wire 161, the motor, the wire 162, the stationary contact 159, the movable contact 157, the stationary contact 160 and the wire 163 to the return line.

In Figure 12 the direction of rotation of the contact carrier disc 144 is assumed to be counterclockwise as indicated by the arrow and the position of the disc is assumed to be that in which the motor operating circuit has been broken. The contact 159 is so located that when the step S8 has been completed (the contact S8*a* at such time moving beyond the contact 149) the contact 157 will immediately thereupon move beyond the stationary contact 159 which will then be in the gap 158 as shown in Figure 12. Thereby the operating circuit for the motor 155 is broken to enable the removal of the processed work unit and the substitution of an unprocessed unit. When this has been done the motor starting circuit is closed manually. This circuit includes a wire 164 connected to the same pole of the motor as the wire 162 and extending to a stationary contact 165 shown schematically in Figure 28 and which may be of any suitable construction and a manually operated switch 166 held normally open, the other stationary switch contact 167 being connected by a wire 168 to the return line 156. After the unprocessed work unit has been secured in position in the manner previously described the switch 166 is operated manually to close the motor starting circuit through the contacts 165 and 167. This circuit is traced through the wire 161, the motor, the wire 164, the stationary switch contact 165, the movable contact of the switch, the stationary switch contact 167, and the return wire 156. The closing of the manual switch 166 results in a movement of the contact carrier 144 in which the gap 158 passes beyond the stationary contact 159 at

which time the movable contact **157** again engages both of the stationary contacts **159** and **160**. Thereupon the switch **166** is released and the cycle of operations of the machine is repeated through the motor operating circuit above described.

The motors **37** and **41** for driving the boring bars are connected in the usual manner to the line wires **155** and **156**, illustration of the wiring being unnecessary. In connection with the removal of the processed unit and the substitution of an unprocessed unit it is desirable that the motors **37** and **41** and the boring bars be at rest. For this purpose a master switch **169** of any suitable construction is arranged in one of the line wires, this switch being manually moved to open position as soon as the operating circuit of the motor **145** is automatically broken. When the unprocessed unit has been secured in position the switch **169** is moved to its closed position and thereupon the switch **166** is operated to close the starting circuit for the motor **145**.

Sectional boilers of the general type which utilize superposed units such as the unit U may be made, according to choice, of maximum and smaller diametrical dimensions, the unit U herein shown being assumed to be for a boiler of maximum diametrical dimension. The machine of the invention is available for the different diametrical sizes of boiler sections. In order that it may be used in connection with boiler sections of smaller diameters the bearing blocks **15** and **16** are slidably mounted in openings **170** in the pedestals **2** and **3**. The adaptability of the machine to boiler sections of smaller diameters is simply a matter of adjustment of the positions of the bearing blocks **15** and **16**. The openings **170** are therefore of greater length than the bearing blocks. The bearing blocks are confined in the openings **170** and guided in their adjustable movements by clips **171** (Figures 4 and 6) attached to the bearing blocks at their opposite sides and projecting laterally to overlie the adjacent bars of the pedestals **2** and **3**. Any suitable mechanism may be provided for the adjustable positioning of the bearing blocks **15** and **16**. As shown in Figures 4 and 6 this mechanism comprises suitably manually operated gearing which includes a transverse operating shaft **172** mounted adjacent the pedestal **2** in bearing brackets **173** and carrying a hand wheel **174**. The gearing also includes shafts **175** arranged at each side of the machine and journalled in bearings **176** carried by and projecting laterally from the pedestals **2** and **3**. The shafts **175** are driven from the shaft **172** by bevel gears **177**. The shafts **175** are each provided at each end thereof with worms **178**. These mesh with worm wheels **179** fitted upon threaded posts **180**, the worm wheels having internal threads to mesh with the threads of the posts. The posts **180** at their inner ends are suitably connected to the bearing blocks **15** and **16**. It will be apparent that when the shaft **172** is turned the worm wheels **179** will be rotated to effect axial movements of the posts **180** and thereby to effect movements of the bearing blocks within the openings **170**. For the boiler sections of maximum diameter the bearing blocks are shown in their lowermost positions. When the machine is to operate on sections of less than maximum diameter the bearing blocks are adjusted upwardly in the openings **170** to positions in which the boring heads **10** will be alined with the two lower openings of the work unit and the lower work engaging elements **60** are appropriately relocated. It will be understood, with reference to the particular form of unit shown, that the upper boring bar **4** does not require an adjustable mounting. It will also be understood that when a change is to be made, from a work unit of smaller diameter to one of larger diameter, the shaft **172** is turned in the direction required to move the bearing blocks downwardly to the appropriate position.

In the cases of the uppermost and lowermost boiler sections the extensions K will, of course, require but one opening in which case the operation of the boring heads **10** is stopped when the boring heads are in the positions shown in broken lines in Figure 16. It will of course be understood that in an operation of this character an appropriate contact carrier disc **144** is to be substituted for the disc shown.

The graphs of Figures 29 and 30 and the diagrams of Figures 31 through 37 illustrate the cutting of tapers in openings of parallel walls in cases where it is desirable that the minimum diameters of the tapers be in extreme relation and the maximum diameters be in mean relation and assume any structural element **U1** having parallel walls with alining openings. In this operation the machine is unchanged, that is to say the combination of cooperating means or mechanisms is as described. However the cutters **35** and **36** which move away from the axis X as the boring head is advanced have the greater projection from the periphery of the boring head and are the "first" cutters and the cutters **33** and **34** which move toward the axis X as the boring head is advanced are the "second" cutters. Hence the steps and sequences of relative movement of the boring bar and the work differ from those described. It will therefore be understood that an appropriate governing element is substituted for the element **144**, the substituted element being similar structurally to the element **144** but of suitably different design (deemed unnecessary to illustrate) in respect to the contacts which it carries for completing and breaking the circuits of the solenoids **139** and **139***a*.

In this operation the work **U1** has four vertical planar positions indicated respectively in Figures 31, 32, 34 and 35 as **B1**, **C1**, **D1**, and **E1** and the boring head has four positions indicated respectively in Figures 31, 33, 34 and 36 as **F1**, **G1**, **H1** and **I1**.

Figure 31 shows the work and the boring head in relatively inactive positions. In this figure the unit **U1** is in position **B1** and is suitably spaced back of the boring head **10** which is in position **F1**.

The first step in this operation of the machine is shown in Figure 32. In this step, while the boring head remains stationary in position **F1**, the work is advanced to position **C1** in which the opening O of the wall A is operatively presented to the cutters **35** and **36**. With the work remaining in position **C1** the boring head is advanced in a direction opposite to the advancing movement of the work to its position **G1** as shown in broken lines in Figure 32 and in solid lines in Figure 33, whereby the cutters **35** and **36** are fed through the anterior opening O and cut the required taper of its wall, this taper being sufficiently shown in Figures 32 and 33 by resort to the expedient of dot and dash extension lines. When the taper of the anterior opening O has been cut as shown in Figure 33 the boring bar and the work are simultaneously moved, the work being moved to position **D1** and the boring bar to position **H1**. With the boring bar remaining in position **H1** the work is moved to position **E1**, thereby to present the posterior opening O to the cutters **33** and **34**. With the work remaining in position **E1** the boring head is again advanced in a direction opposite to the advancing movement of the work to its position **I1** as shown in broken lines in Figure 35 and in solid lines in Figure 36, whereby the cutters **33** and **34** are fed through the posterior opening O and cut the required taper of its wall, this taper being sufficiently shown in Figures 35 and 36 by resort to the expedient of dot and dash extension lines.

It is to be noted that in the position **I1** of the boring head as shown in Figure 36 the leading edge of the cutter **34** is moved sufficiently beyond the posterior face of the posterior wall to provide clearance for the movement of the work in its retractile step. In such movement, effected while the boring head remains in its position **I1**, the work is shifted back from its position **E1** to its original position **B1** as shown in Figure 37. In this step the cutters are freed from the opening in the wall P. Thereupon the boring head is shifted from its position **I1** back

to its original inactive position as shown in Figure 37 in which position the cutters are withdrawn from the opening in the anterior wall. The processed unit U1 is thereupon removed from the carrier and a unit requiring processing is mounted, the cycles of operation then being repeated.

By way of recapitulation the steps of movement of the work and the boring head when the tapers are to be cut with their minimum diameters in extreme relation are graphically illustrated in Figures 29 and 30 which are to be read together and, respectively, illustrate the cycles of movements of the boring head and the work.

Figures 29 and 30 are to be considered in relation to the previous description of the several steps as based upon the disclosures of Figures 31 through 37. With the boring head in position F1 and the unprocessed work unit in position B1 (Figure 31) the first step S1*a* (Figure 30) is movement of the work from position B1 to position C1 (Figure 32). With the work in position C1 the second step S2*a* (Figure 29) is the cutter feeding movement of the boring head from position F1 to position G1 (Figures 32 and 33) in which the cutters form the taper of the wall of the anterior opening O. The third and fourth steps S3*a* (Figure 30) and S4*a* (Figure 29) are effected simultaneously and involve the movement of the work to position D1 and the movement of the boring head to position H1 (Figure 34). The fifth step S5*a* (Figure 30) is the movement of the work from position D1 to position E1 (Figure 35). With the work in position E1 the sixth step S6*a* (Figure 29) is the cutter feeding movement of the boring head from position H1 to position I1 (Figures 35 and 36) in which the cutters form the taper of the wall of the posterior opening O. The seventh step S7*a* (Figure 30) is the retractile movement of the work from position E1 to its original position B1 (Figure 37). The eighth and final step S8*a* (Figure 29) is the retractile movement of the boring head from its position I1 to its original position F1 (Figure 37).

Referring to Figure 38:

In the modified construction shown schematically in Figure 38 the mounting of the spindle **9** in the driving element and its operative connection to it are as previously described. According to the modification the work unit is mounted in a fixed position and the driving element is supported by a movable carrier, the relative rectilinear movements of the driving element and the work unit being provided by absolute rectilinear movements of the driving element.

The work unit is secured in a frame **46***a* of the same general construction as the frame **46**, the work unit clamping means being of the character described. The frame **46***a* is in a transverse plane and is bolted to a fixed supporting base **181** in the form of a plate which is mounted upon and spaced above the frame base **1**. The driving element **5***a* is similar in all respects to the driving element **5**, from which it differs only in that it is supported by a movable carrier **44***a*. This includes a base **45***a* mounted upon the frame base in the same way as the base **45** of the carrier **44**. The base **45***a* carries upright front and rear pedestals **2***a* and **3***a* arranged in transverse planes and similar in all respects to the pedestals **2** and **3**. The driving elements **5***a* are mounted in the pedestals **2***a* and **3***a* in the same manner that the driving elements **5** are mounted in the pedestals **2** and **3**.

In the modified construction the movements of the spindles **9** are effected by collars **30***a* operated by a spider **72***a*, the collars **30***a* and spider **72***a* being similar in all respects to the collars **30** and spider **72**. The spider **72***a* is operated by a fluid motor **77***a*, the stem **81***a* of which is connected to a bracket **80***a* secured to the pedestal **3***a*, the motor **77***a*, its piston stem **81***a* and the bracket **80***a* being similar in all respects to the motor **77**, its piston stem **81** and the bracket **80**. The boring heads **10***a* are similar in all respects to the boring heads **10** and are similarly secured for rotatable adjustment to the spindles **9**. When the spindles are moved in either direction along their inclined paths the boring heads **10***a* are moved relatively to the driving element **5***a* and to the work in the same way that the boring heads **10** are moved relatively to the driving head **5** and the work. The movements of the carrier **44***a* are effected by a fluid motor **64***a* similar in all respects to the motor **64**. The motor **64***a* is accommodated in the space **182** below the base **181**, the movable cylinder of the motor being connected to the carrier base **45***a* and the piston stem **66***a* being secured to a lug **68***a* mounted on the frame base **1** in the same manner that the piston stem **66** is secured to the lug **68**.

The modified construction includes the solenoids **139** and **139***a*, the valves **96** and **96***a*, the governing element **144** and the motor **145** for driving the governing element. The illustration of these parts in Figure 38 is deemed unnecessary since they are the same as in the preferred embodiment, the liquid flow paths for the fluid motors and the circuits for the solenoids and the motor **145** being as previously described. It will be sufficient to point out that these parts may be mounted upon the base **45***a* of the carrier **44***a* and that flexible tubing, as may be required by details of arrangement, may be used to provide the liquid flow tubes.

It will be obvious that the modified construction is available for the same steps and sequences of relative movements of the boring bar drive element, the work and the boring heads that have been previously described and are shown in respect to tapers having their maximum diameters in extreme relation in the graphs of Figures 13 and 14 and the diagrams of Figures 15 through 20 and in respect to tapers having their minimum diameters in extreme relation in the graphs of Figures 29 and 30 and the diagrams of Figures 31 through 37.

I claim:

1. In a machine for boring oppositely tapering coaxial holes in spaced wall parts, in combination: a boring bar including a driving element in the form of a straight hollow shaft, journals carried by the driving element at its opposite ends, the journals being concentric to a major axis and the driving element extending along an axis inclined relatively to the major axis and in intersecting relation thereto, a spindle mounted within and supported by the driving element and extending along the inclined axis of the driving element, the spindle being slidable relatively to the driving element in the direction of the inclined axis, the driving element being rotatable about the major axis, means carried by the spindle and participating in its sliding movement for connecting the spindle to the driving element for rotation with it about the major axis, a boring head secured to the spindle beyond and adjacent the point of intersection of the axis of the driving element and the major axis and in projecting relation to the driving element, the boring head having a central axis which extends in the same direction as the major axis, and cutters carried by the boring head, projecting radially from it and positioned in diametrically opposite relation with greater and less degrees of projection, respectively, from the boring head; supporting means for the boring bar including spaced pedestals between which the driving element extends; bearings for the journals associated with the pedestals and being concentric with the major axis; means located beyond the boring head for supporting work unit in a plane normal to the major axis, the work unit having an opening in the annular wall of which a taper is to be cut, the work unit being held by its supporting means in a position wherein the central axis of the opening is coincident with the major axis; the supporting means for the boring bar and the work unit being companion elements, one of which is mounted for rectilinear movement relatively to the other; the spindle being slidably movable in one direction to feed the cutters through the openings in the walls of which the tapers are to be cut and being slidably movable in retraction in the opposite direction; movable means operatively connected to

the spindle for effecting its slidable movements in either direction; motor means drivingly connected to the spindle moving means for effecting the movement thereof in either direction; motor means drivingly connected to the movably mounted companion element for effecting the rectilinear movement thereof in either direction; a cyclically movable element for governing the operation of both motor means and having parts severally operable in respect to predetermined extents, sequences, and directions of the steps of movement of the spindle and the movably mounted companion element and the periods of rest of the spindle and the movably mounted companion element between their respective sequential steps of movement; means of operative connection severally between the parts of the governing element and the respective motor means; a motor drivingly connected to the governing element for effecting its cyclical movement; and motor means drivingly connected to the boring bar for effecting the rotation of its hollow shaft about the major axis.

2. A machine as set forth in claim 1 wherein the boring head is positionally rotatably adjustable about its central axis.

3. A machine as set forth in claim 1 wherein the means connecting the driving element and the spindle consists of a diametrically arranged key, the driving element has a face of cylindrical outline concentric with the major axis and having a longitudinal slot, the key projects through the slot and beyond the face of cylindrical outline, and the means for effecting the slidable movements of the spindle includes a collar slidably mounted upon the cylindrical face of the driving element and having an opening to accommodate with a driving fit the part of the key which projects beyond the driving element.

4. A machine as set forth in claim 1 having a plurality of similar boring bars and wherein the spindles of the boring bars are moved slidably simultaneously in the same directions and to the same extent, wherein the means for effecting the slidable movement of the spindles includes a rectilinearly movable element operatively connected to each of the spindles and wherein the motor means for effecting the movement of the spindle moving means is drivingly connected to said element.

5. A machine as set forth in claim 3 having a plurality of similar boring bars and collars slidably mounted upon the cylindrical faces of the driving elements and wherein each collar is formed with a circumscribing flange in a plane normal to the major axis, wherein the means for effecting the axial slidable movement of the spindles includes a rectilinearly movable element having projecting arms severally for engagement with the flanges of the collars whereby to move the collars in either direction, and wherein the motor means for effecting the movement of the spindle moving means is drivingly connected to said element.

6. A machine as set forth in claim 1 wherein each motor means consists of a fluid motor having as relatively movable companion elements a cylinder and a piston and wherein the means of operative connection severally between the parts of the governing element and the respective motor means includes a valve for controlling the fluid flow paths of each motor means, each valve having a movable valve body, the position of which determines the particular flow path or the occlusion of the flow paths, a double acting solenoid is provided for each valve and has its armature normally in a neutral position and operatively connected to the body of the valve, the solenoids each having opposed windings and each winding being in a circuit having fixed contacts, and the cyclically movable element is provided with contacts severally for engagement with the fixed contacts, the latter contacts being of extent and arrangement to control selectively the energization of a particular winding of either solenoid and to determine the duration of its energization.

7. A machine as set forth in claim 1 wherein the pedestals are fixedly mounted and the supporting means for the work unit is the companion element which is mounted for rectilinear movement.

8. A machine as set forth in claim 1 wherein the supporting means for the work unit is fixedly mounted and the supporting means for the driving element is the companion element which is mounted for rectilinear movement.

9. In a machine for boring oppositely tapering coaxial holes in spaced wall parts, in combination: a boring bar including a driving element in the form of a straight shaft, journals carried by the driving element at its opposite ends, the journals being concentric to a major axis and the driving element extending along an axis inclined relatively to the major axis and in intersecting relation thereto, a spindle supported by the driving element and extending along the inclined axis of the driving element, the spindle being axially slidable relatively to the driving element, means connecting the driving element and the spindle for rotation about the major axis in any position of the spindle relatively to the driving element within the limits of its slidable movement, a boring head secured to the spindle beyond and adjacent the point of intersection of the axis of the driving element and the major axis and in projecting relation to the driving element, the boring head having a central axis which extends in the same direction as the major axis, and cutters carried by the boring head, projecting radially from it and positioned in diametrically opposite relation with greater and less degrees of projection, respectively, from the boring head; supporting means for the driving element including spaced pedestals between which the driving element extends; and bearings for the driving element associated with the pedestals and being concentric to the major axis.

10. A machine as set forth in claim 9 wherein the boring head is positionally rotatably adjustable about its central axis.

11. In a machine for boring oppositely tapering coaxial holes in spaced wall parts, in combination: a boring bar including a driving element in the form of a straight hollow shaft, journals carried by the driving element at its opposite ends, the journals being concentric to a major axis and the driving element extending along an axis inclined relatively to the major axis and in intersecting relation thereto, a spindle mounted within and supported by the driving element and extending along the inclined axis of the driving element, the spindle being slidable relatively to the driving element, in the direction of the inclined axis, the driving element being rotatable about the major axis, means carried by the spindle and participating in its sliding movement for connecting the spindle to the driving element for rotation with it about the major axis, a boring head secured to the spindle beyond and adjacent the point of intersection of the axis of the driving element and the major axis and in projecting relation to the driving element, the boring head having a central axis which extends in the same direction as the major axis, and cutters carried by the boring head, projecting radially from it and positioned in diametrically opposite relation with greater and less degrees of projection, respectively, from the boring head; supporting means for boring bar including spaced pedestals between which the driving element extends; bearings for the journals associated with the pedestals and being concentric with the major axis; means located beyond the boring head for supporting a work unit in a plane normal to the major axis, the work unit having an opening in the annular wall of which a taper is to be cut, the work unit being held by its supporting means in a position wherein the central axis of the opening is coincident with the major axis; the supporting means for the boring bar and the work unit being companion elements, one of which is mounted for rectilinear movement relatively to the other; the spindle being slidably movable in one direction to

feed the cutters through the openings in the walls of which the tapers are to be cut and being slidably movable in retraction in the opposite direction; movable means operatively connected to the spindle for effecting its slidable movements in either direction; motor means drivingly connected to the spindle moving means for effecting the movement thereof in either direction; motor means drivingly connected to the movably mounted companion element for effecting the rectilinear movement thereof in either direction; and motor means drivingly connected to the boring bar for effecting the rotation of its hollow shaft about the major axis.

12. A machine as set forth in claim 11 wherein the boring head is positionally rotatably adjustable about its central axis.

13. A machine as set forth in claim 11 wherein the means connecting the driving element and the spindle consists of a diametrically arranged key, the driving element has a face of cylindrical outline concentric with the major axis and having a longitudinal slot, the key projects through the slot and beyond the face of cylindrical outline, and the means for effecting the slidable movements of the spindle includes a collar slidably mounted upon the cylindrical face of the driving element and having an opening to accommodate with a driving fit the part of the key which projects beyond the driving element.

14. A machine as set forth in claim 11 having a plurality of similar boring bars and wherein the spindles of the boring bars are moved slidably simultaneously in the same directions and to the same extent, wherein the means for effecting the slidable movement of the spindles includes a rectilinearly movable element operatively connected to each of the spindles and wherein the motor means for effecting the movement of the spindle moving means is drivingly connected to said element.

15. A machine as set forth in claim 13 having a plurality of similar boring bars and collars slidably mounted upon the cylindrical faces of the driving elements and wherein each collar is formed with a circumscribing flange in a plane normal to the major axis, wherein the means for effecting the axial slidable movement of the spindles includes a rectilinearly movable element having projecting arms severally for engagement with the flanges of the collars whereby to move the collars in either direction, and wherein the motor means for effecting the movement of the spindle moving means is drivingly connected to said element.

16. A machine as set forth in claim 11 wherein the pedestals are fixedly mounted and the supporting means for the work unit is the companion element which is mounted for rectilinear movement.

17. A machine as set forth in claim 11 wherein the supporting means for the work unit is fixedly mounted and the supporting means for the driving element is the companion element which is mounted for rectilinear movement.

References Cited in the file of this patent

UNITED STATES PATENTS

415,845	Richards	Nov. 26, 1889
521,922	Stevenson	June 26, 1894
1,893,810	Travis	Jan. 10, 1933
2,131,468	Ames et al.	Sept. 27, 1938
2,305,812	Regul	Dec. 22, 1942