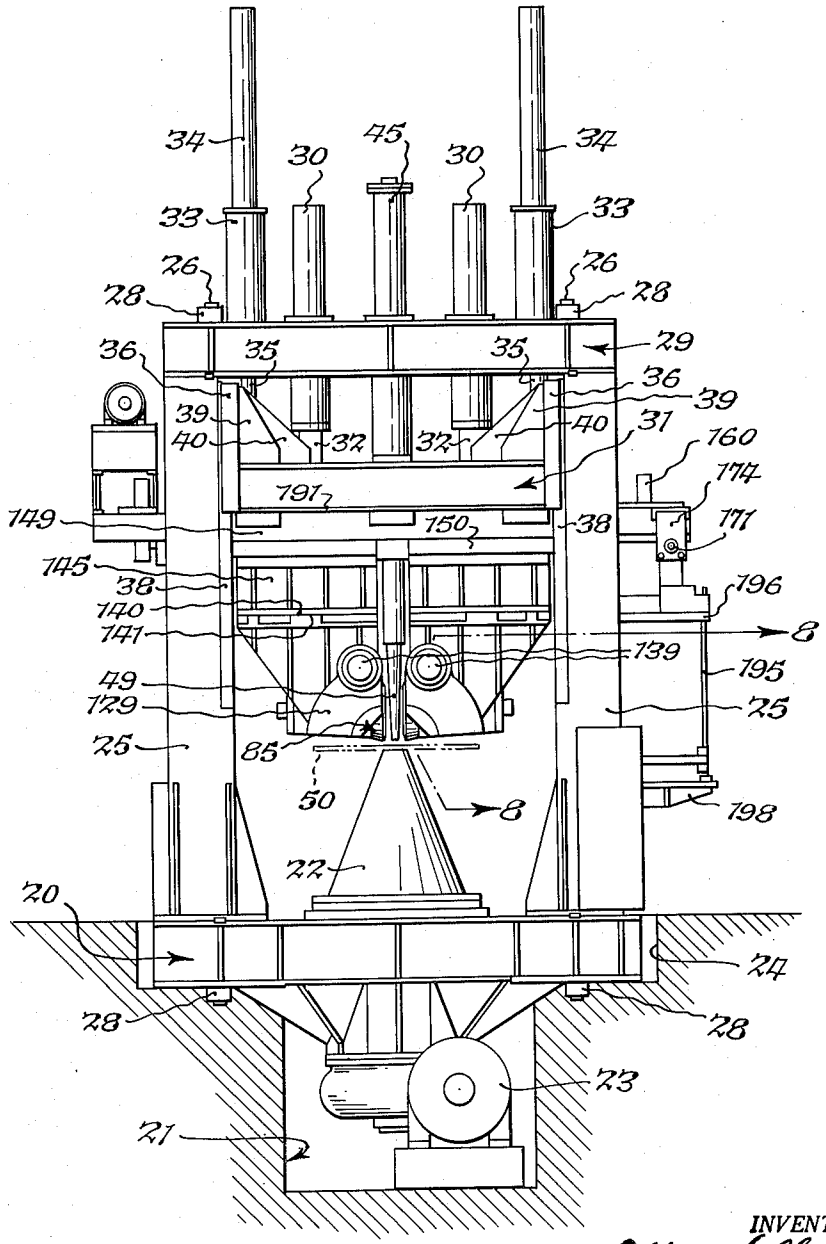
March 21, 1961 O. HOFFMANN ET AL 2,975,743

METAL FORMING MACHINE

Filed May 18, 1956 7 Sheets-Sheet 1

Fig. 1.



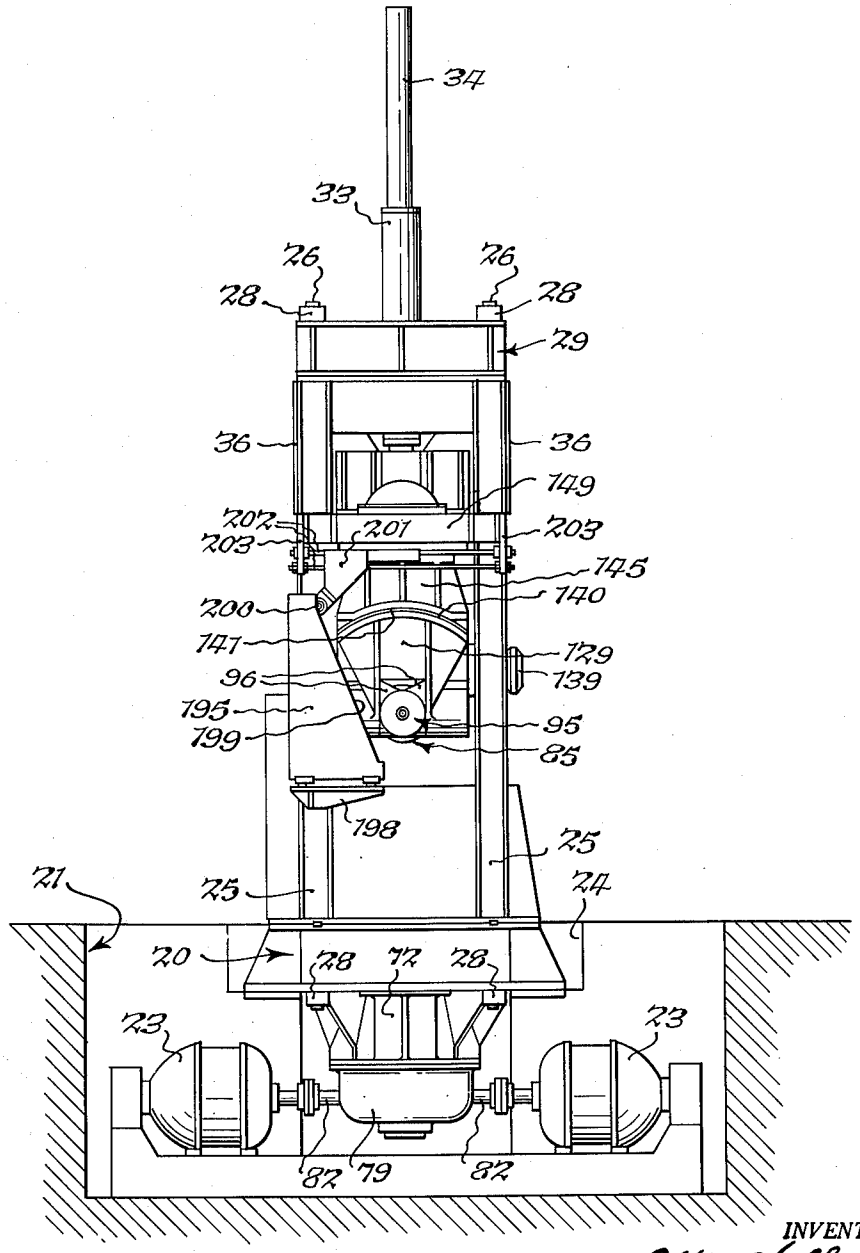
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METAL FORMING MACHINE

Filed May 18, 1956 7 Sheets-Sheet 2

Fig. 2.



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METAL FORMING MACHINE

Filed May 18, 1956 7 Sheets-Sheet 3

Fig. 3.

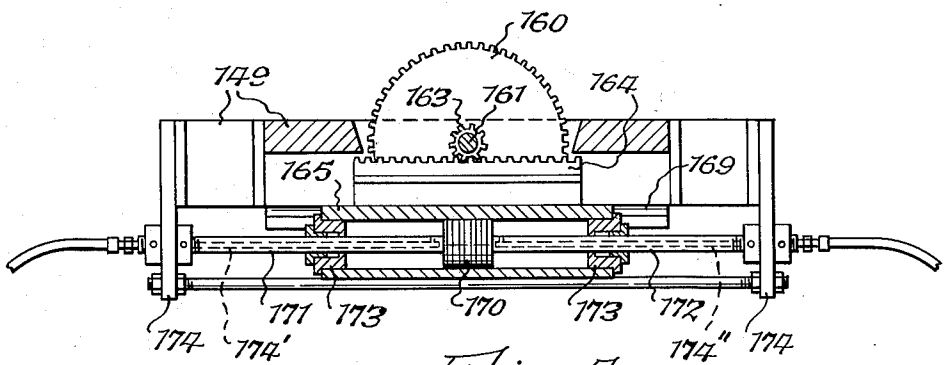
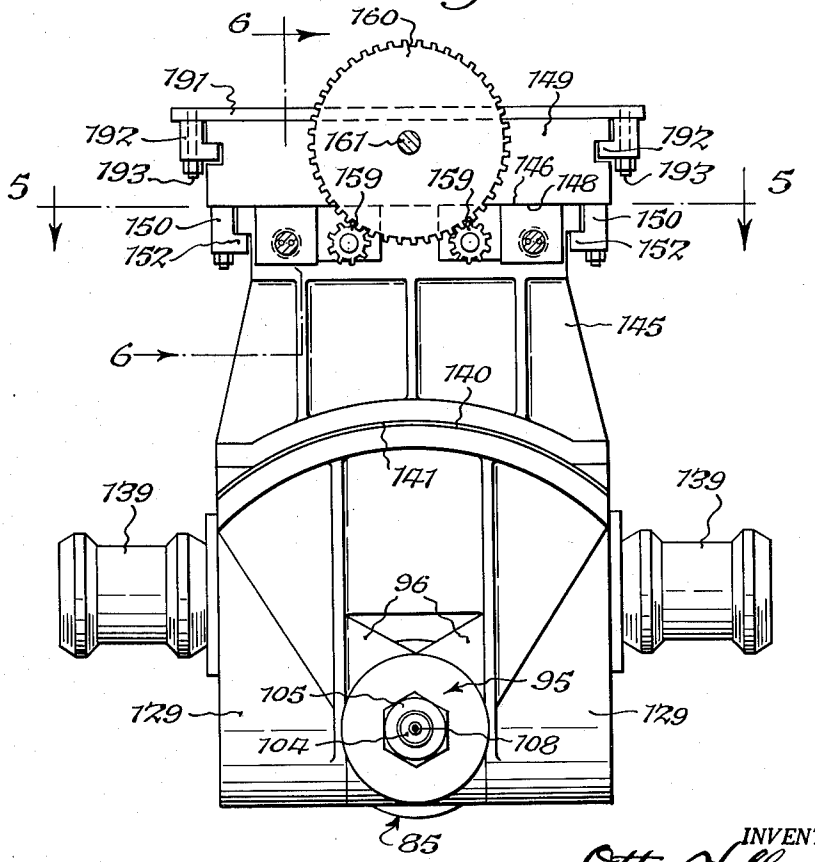


Fig. 4.



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METAL FORMING MACHINE

Filed May 18, 1956 7 Sheets-Sheet 4

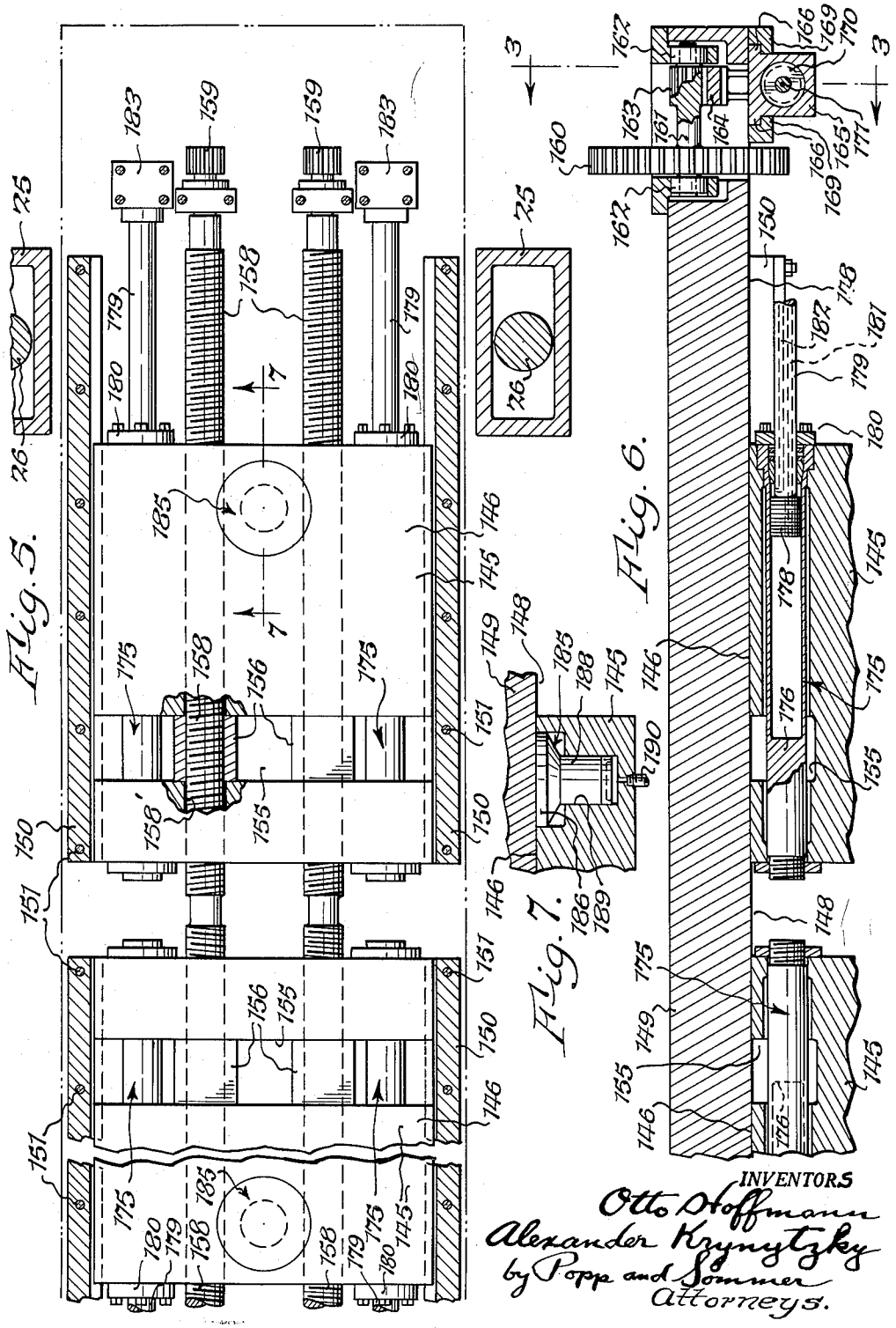


Fig. 5.

Fig. 6.

Fig. 7.

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METAL FORMING MACHINE

Filed May 18, 1956 7 Sheets-Sheet 5

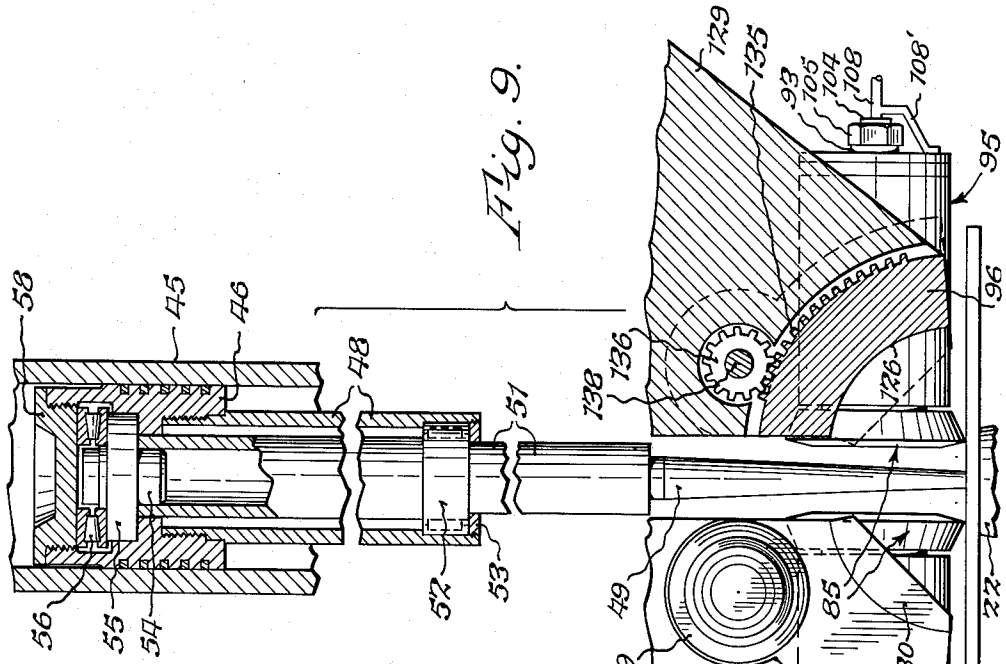


Fig. 9.

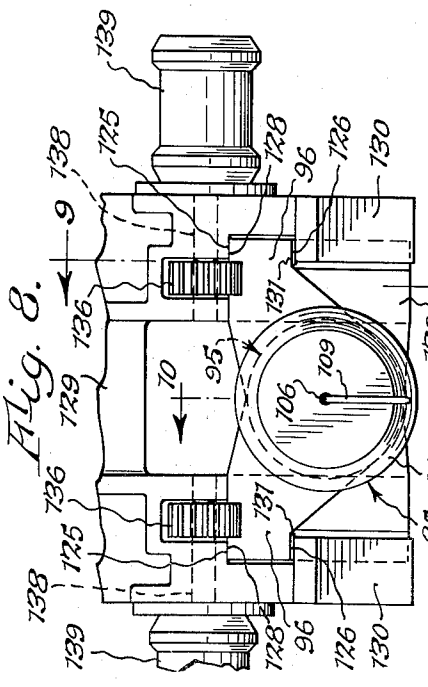


Fig. 8.

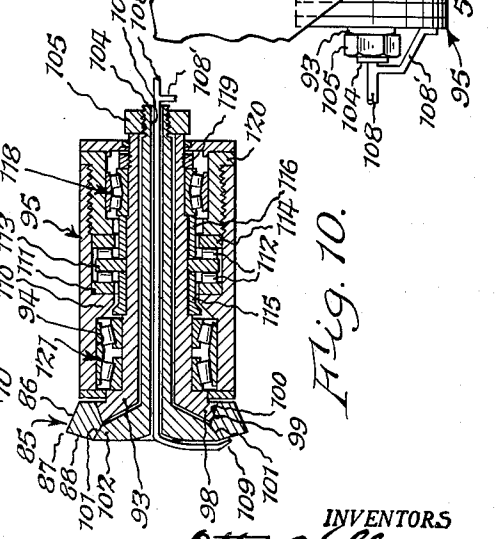


Fig. 10.

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March 21, 1961 O. HOFFMANN ET AL 2,975,743

METAL FORMING MACHINE

Filed May 18, 1956 7 Sheets-Sheet 6

Fig. 12.

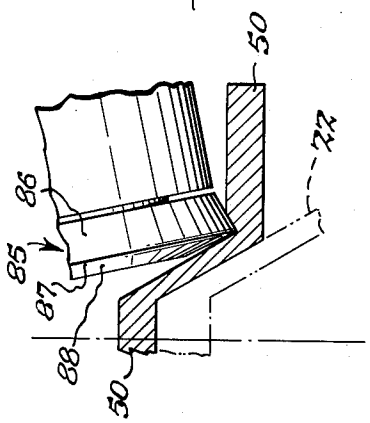


Fig. 13.

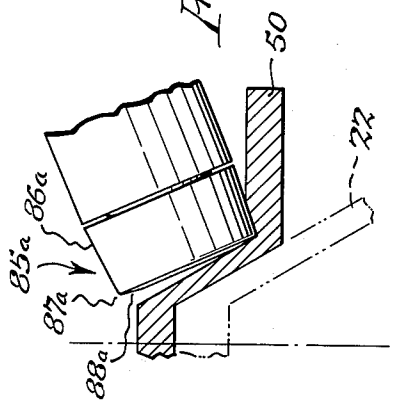
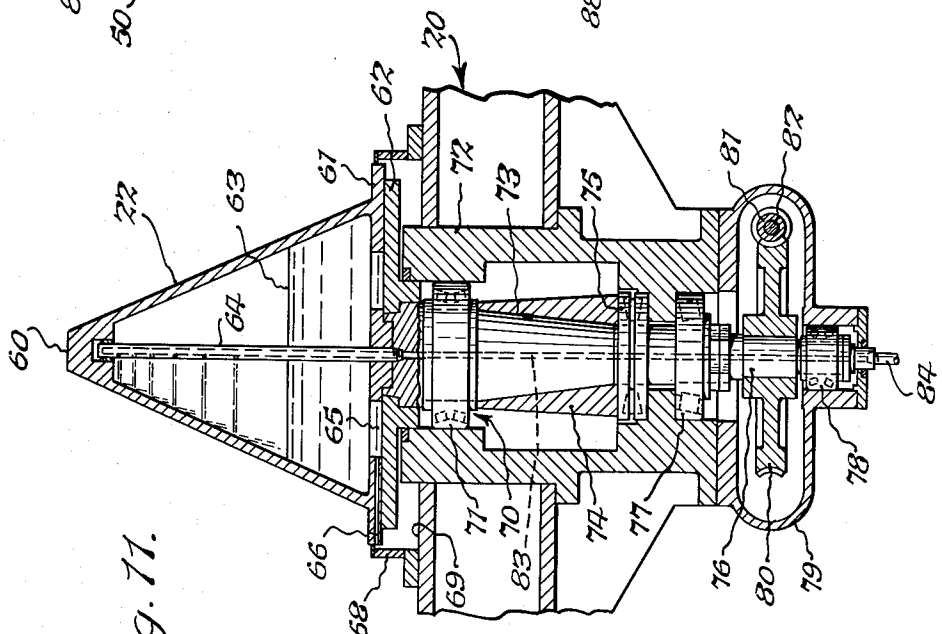


Fig. 11.



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March 21, 1961 O. HOFFMANN ET AL 2,975,743

METAL FORMING MACHINE

Filed May 18, 1956 7 Sheets-Sheet 7

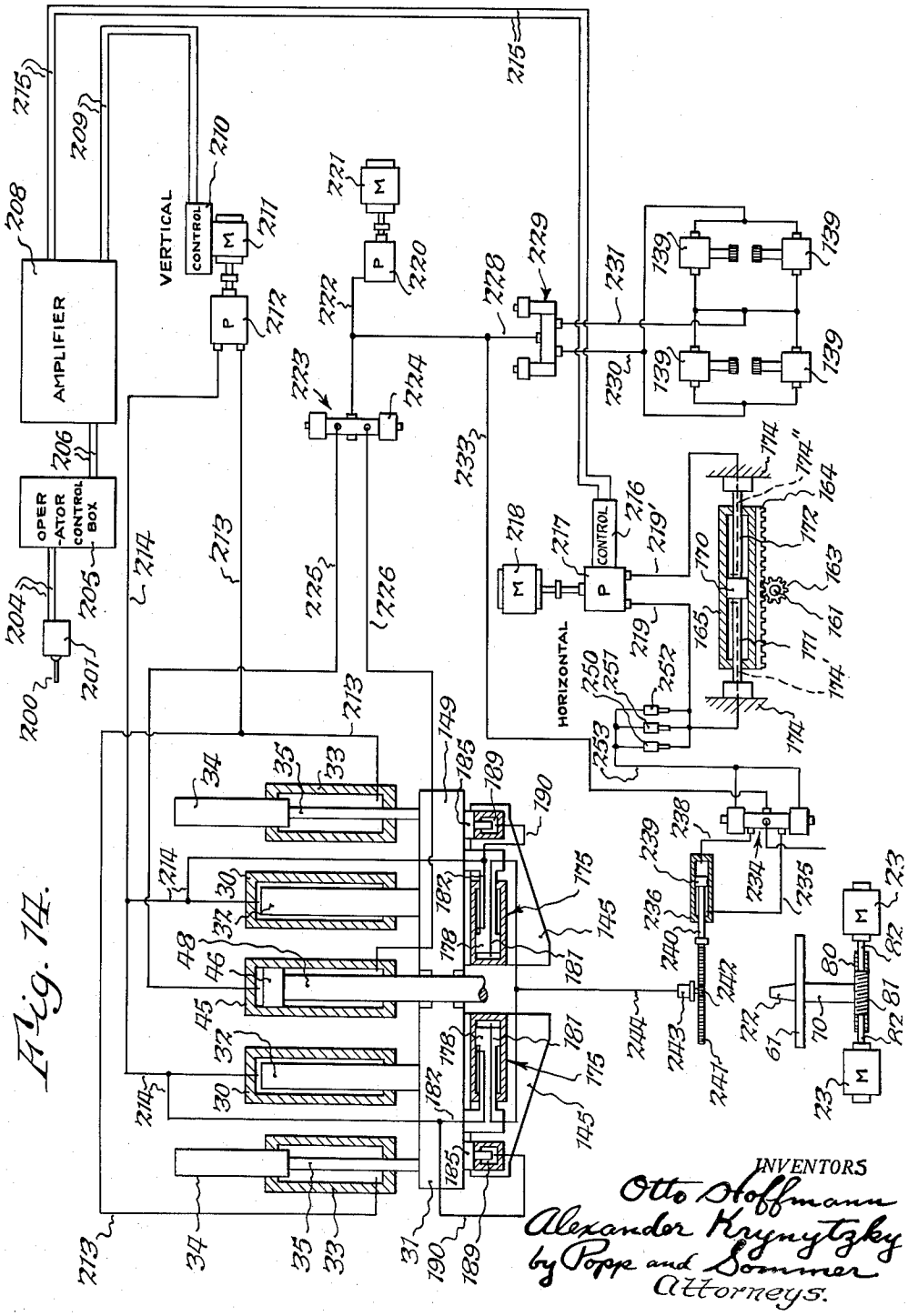


Fig. 14.

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United States Patent Office 2,975,743
Patented Mar. 21, 1961

2,975,743

METAL FORMING MACHINE

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Filed May 18, 1956, Ser. No. 585,686

13 Claims. (Cl. 113—53)

This invention relates to a rotary metal forming machine and more particularly to such a machine which will cold form a flat or preformed metal blank into circular hollow shapes, such as cones, semispheres or combinations of both, by rolling the blank against a properly shaped revolving mandrel with two forming rolls spaced 180° apart and constrained to produce a predetermined thickness or form in the material in two continuous helical paths while traveling lengthwise of the axis of the revolving mandrel.

A most important object of the present invention is to provide such a metal forming machine in which the plastic deformation of the material is performed through a true rolling action of the forming rolls against the material in contrast to the combined rolling and sliding action performed by the forming rolls of conventional metal forming machines of this general type. Through this true rolling action as compared with the conventional combined rolling and sliding action, a better surface finish can be obtained since the rolling faces of the forming rolls act as a polishing tool to work on the remainder of the working surface. By effecting the deformation work by pure rolling a free grain flow is accomplished, thus avoiding any galling or pinching of the metal. With such pure rolling action there is less heat generation and therefore the deformation is effected at lower temperature and more work can be accomplished with a given horsepower.

Another object of the invention is to provide such a machine in which the desired form can be produced in fewer passes as compared with conventional machines of this type.

Another object is to provide an improved mounting for the forming rolls which provides a greater degree of flexibility in positioning the forming rolls with reference to the workpiece in obtaining the optimum action, particularly in obtaining closer clearances between the forming rolls and the revolving mandrel as compared with conventional machines.

Another object is to provide such an improved mounting for the forming rolls in which the forming rolls can be moved to change their effective geometrical shape without interfering with the work.

Another object is to provide such an improved mounting for the forming rolls in which adjustable carriers for the forming rolls can be turned about horizontal axes to a degree which will permit the rolls to be used for tube upsetting operations. Such adjustability permits flanging, upsetting and similar operations within very close tolerances.

Another object is to provide a sideways adjustment for each forming roll which allows the roll to be adjusted to have a sideways tilt to achieve a more efficient tool setting by providing a side relief angle similar to the common cutting tool.

Another object is to provide an improved mounting for the forming rolls which permits adjustment of the forming rolls to exact concentricity with reference to each

other or by which the two forming rolls can be intentionally offset in order to use the rolls for two different passes if advisable. Thus one roll only could be used for lighter work by tilting the other out of the way.

Another object is to provide such an improved mounting for the forming rolls in which the movement of their holders toward and from the axis of rotation of the mandrel is equalized mechanically with both forming rolls being controlled from one tracking unit and one template.

Another object is to provide such a metal forming machine in which the mandrel rotates about a vertical axis with the workpiece formed downwardly on the workpiece by descending forming rolls which are constrained to move horizontally during their descent to produce the desired shape. By such vertical forming greater accuracy in clamping and forming the workpiece is possible since the unbalancing effect of gravity is not encountered. The horizontal movement of the forming rolls is preferably a direct function of the vertical movement thereof.

Another object is to relieve the load upon the screws, used to move the forming rolls toward each other, by a hydraulic pressure which is varied in response to the working load upon the screws so as to reduce the friction and load upon the screws to a minimum constant. This also reduces the power requirement to move the forming rolls toward each other to a minimum.

Another object is to provide such an improved mounting for the pair of slides each equipped with a vertically acting piston and cylinder positioned so that the piston acts as a jack ram to eleminate possible wedging of the slides under certain unfavorable force distributions.

Another object is to provide room for mandrel turning and grinding attachments for operation on either the mandrel or the workpiece, this being accomplished by rendering the holders for the forming rolls detachable. This permits facing and cut-off operations on the workpiece without removing the workpiece from the mandrel and also permits the forming mandrels to be finished in place in the machine.

Another object is to provide for the rapid removal of the heat generated at the contact area between the forming rolls and the workpiece, such heat being desirably removed both by internal cooling of the mandrel and also by directing a coolant against the forming roll at its place of contact with the workpiece.

Another object of the invention is to provide such a metal forming machine in which the speed of travel of the forming rolls lengthwise of the axis of the rotary mandrel is determined by the shape being formed and in which the speed of the motors driving the mandrel can be adjusted to provide optimum forming action.

Another object is to provide such a metal forming machine which can be made as a heavy duty machine to form blanks having a thickness of as much as 1½ inches without producing chips or other metal particles and at a speed faster than conventional machines of this general type.

Another object is to provide such a machine in which the product has improved physical properties without special alloy stock or heat treatment processes, this being achieved by rolling and working the metal to provide a refined grain structure.

Another object is to provide such a metal forming machine which can be rendered fully automatic.

Another object is to provide such a machine which is of sturdy construction and rigid and compact design and which will stand up under conditions of severe and constant use without getting out of order or requiring repairs.

Other objects and advantages of the invention will be

apparent from the following description and drawings in which:

Fig. 1 is a front elevational view of a rotary metal forming machine embodying the present invention.

Fig. 2 is a side elevational view.

Fig. 3 is an enlarged fragmentary vertical section taken generally on line 3—3, Fig. 6 through a sliding cylinder and a reciprocating holder which turn the double ended screws to draw the forming rolls toward each other.

Fig. 4 is a side elevational view of the reciprocating and adjustable holders for the forming rolls and showing the manner in which they are secured to the underside of the movable ram of the machine.

Fig. 5 is a fragmentary horizontal sectional view taken on line 5—5, Fig. 4 and showing, in plan, the two reciprocating holders for the two forming rolls and the manner in which these reciprocating holders, and hence the forming rolls, are moved toward and from each other by double ended screws.

Fig. 6 is a fragmentary vertical section taken generally on line 6—6, Fig. 4 and illustrating in particular one of the cylinders containing a piston which relieves a companion screw from the greater part of the work in moving the forming roll with reference to the workpiece during the forming operation.

Fig. 7 is a fragmentary vertical section taken generally on line 7—7, Fig. 5 and showing the piston provided on each reciprocating tool holder to act as a jack ram in eliminating the possibility of wedging these reciprocating holders under certain unfavorable conditions.

Fig. 8 is an enlarged fragmentary vertical section taken generally on line 8—8, Fig. 1, and showing, in elevation, the reciprocating and adjustable holders for the forming rolls as well as showing one of the forming rolls in end elevation.

Fig. 9 is a fragmentary vertical section taken generally on line 9—9, Fig. 8 and illustrating the adjustable mounting for the forming rolls, this view also showing the tailstock as well as showing in section the piston and cylinder for moving this tailstock into clamping engagement with the workpiece.

Fig. 10 is a vertical section taken generally on line 10—10, Fig. 8 and showing the manner in which each forming roll is rotatably and detachably mounted.

Fig. 11 is a vertical central sectional view through the rotary mandrel on which the workpiece is formed and showing the manner in which this mandrel is driven and cooled.

Fig. 12 is a further enlarged fragmentary side elevation of the forming roll illustrating the manner in which the workpiece is deformed by a pure rolling action in contrast to the rolling and sliding action which obtains with conventional practices.

Fig. 13 is a view similar to Fig. 12 showing a modified form of forming roll.

Fig. 14 is a simplified diagrammatic representation of the hydraulic and electrical circuits for the metal forming machine.

In general, the rotary metal forming machine of the present invention is shown as embodied in a press of the downstroke, four-column housing type having top and bottom stationary platens rigidly connected by four heavy columns. Two working cylinders, two pull-back cylinders as well as a tailstock clamping cylinder are inserted into the top stationary platen and the pistons of the working and pull-back cylinders are securely fastened to the vertically movable platen or ram which is guided throughout its full length of stroke between the top and bottom stationary platens. The top stationary platen of the press is of a heavy box type welded steel construction, bored for the snug fitting of the two working cylinders, the two pull-back and one double acting tailstock clamping cylinder. The moving platen or ram is also of a heavy box type welded steel construction machined across its top surface for the attachment of the cylinder rams and across its bottom surface for attachment of a bolster plate with the two reciprocating holders for the metal forming rolls. This moving platen is arranged to have the clamping cylinder ram of the tailstock passing through the center. The bottom stationary platen or bed is of heavy box type welded steel construction with a cast steel center for the mandrel mounting.

More specifically, the rotary metal forming machine of the present invention is shown as including a heavy box type welded base or bed forming a bottom fixed platen, indicated generally at 20, mounted to extend transversely over a pit 21 and supporting an upwardly projecting mandrel 22 which is rotated about a vertical axis by a pair of motors 23 arranged in the pit 21. The bed or bottom stationary platen 20 is shown as set into recesses 24 on opposite sides of the pit 21.

At its corners, the bed or bottom stationary platen 20 supports four heavy vertical corner columns 25 which are designed to resist vertical elongation and hence each is preferably made, as best shown in Fig. 5, of hollow rectangular cross section housing a vertical high tensile steel tie rod 26 provided with nuts 28 at its upper and lower ends, the lower ones of which tighten against the undersides of the base or bottom stationary platen 20 as best shown in Figs. 1 and 2. The upper nuts 28 tighten against the upper face of a top stationary platen 29. This top stationary platen 29 is supported at its corners on the columns 25, the bed or stationary bottom platen 20, and top stationary platen 29 being held together by the tie rods 26.

The top stationary platen 29 supports a pair of vertical working cylinders 30 which serve to force the ram of the movable platen 31 downwardly. For this purpose each working cylinder 30 houses a ram 32 which, as best shown in Figs. 1–14, is fixed at its lower end to the movable platen 31. This top fixed platen 29 also carries a pair of pull-back cylinders 33 which serve to elevate the movable platen 31. For this purpose a pull-back piston 34 projects upwardly from each pull-back cylinder and, as best shown in Figs. 1–14, is connected with the movable platen 31 by a piston rod 35. The movable platen 31 is shown as being generally of rectangular form in plan with its corners arranged adjacent the frame columns 25. At each corner, a vertical slide member 36 is fixed to the movable platen, each slide member sliding along a slideway 38 fixed on the corresponding frame column 25. The slide members 36 can be reinforced by suitable angular reinforcing webs 39 and 40 as shown.

The top fixed platen 29 also carries at its center a vertical tailstock clamping cylinder 45 containing a piston 46 from which a piston rod 48 projects downwardly. This piston rod 48 rotatably supports a tailstock 49 which engages and clamps or holds the center of the workpiece 50 against the center of the mandrel 22. For this purpose, as best shown in Fig. 9, the tailstock 49 is secured in any suitable manner in the lower end of a tubular tailstock holder or vertical shaft 51 which is journalled coaxially within the piston 46 and piston rod 48. The lower roller bearing 52 for the tailstock holder 51 is fitted in the lower end of the tubular piston rod 48 and supported by a screw ring 53 which is screwed into the lower internally threaded end of the tubular piston rod. The upper end of the tubular piston 48 is externally threaded and screwed into the internally threaded lower end of a bore through this piston. The upper end of the tubular tailstock holder 51 extends into the bore of the piston 46 and is fitted to the rotating hub member 54 of a radial bearing 55. The upper end of the rotating hub 54 is engaged by a thrust roller bearing 56 which is held down by a screw cap 58 screwed into the upper end of the piston 46.

It will accordingly be seen that when fluid under pres-

sure is admitted to the upper end of the tailstock cylinder 45, its piston 46 is driven downwardly. Through the screw cap 58 and thrust bearing 56 this forces the tubular tailstock holder 51 and tailstock 49 into clamping engagement with the workpiece 50. During the forming operation the workpiece is rotating with the mandrel 22 over the exterior of which the workpiece is formed. During this rotation of the workpiece and mandrel the tailstock 49 is held in clamping engagement with the workpiece, this being permitted by the radial bearings 52, 55 which journal the tailstock holder 51 in the tubular piston rod 48 and piston 46.

The mandrel 22, rotated about a vertical axis by the two electric motors 23, can be mounted in any suitable manner. As shown in detail in Fig. 11, the mandrel 22 is shown as having a conical external face which conforms to the desired shape of the shell to be formed. This mandrel is shown as being hollow and as having a flattened apex 60 on which the workpiece 50 is placed and as having a flat base 61 removably fixed to a rotating table 62 in any suitable manner. Liquid coolant 63 is supplied to the interior of the mandrel from an upright pipe 64 mounted in the center of the rotating table 62 and this coolant escapes from the mandrel through bottom openings 65 and radial passages 66. The annular curb or rail 68 forms a sump 69 in which the coolant collects to be cooled and recirculated.

The rotating table 62 is fast to the upper end of a vertical spindle 70, the upper end of which is supported in a radial bearing 71 mounted in a vertical bore through a base supporting housing 72, the latter being fixed to the bottom fixed platen or bed 20. The spindle 70 includes a downwardly diminishing taper 73 supported in the tapered bore of a sleeve 74, the latter being supported on a thrust bearing 75 carried by the base supporting housing 72. The spindle 70 includes a downward extension 76, the upper end of which is journalled in a radial roller bearing 77 in the base supporting housing 72 and the lower end of which extension is journalled in a radial ball bearing 78 carried by a gear case 79. The gear case houses a worm wheel 80 fast to the downward extension 76 of the spindle 70 and a worm 81 fast to a horizontal drive shaft 82 which is directly coupled with the shafts of the two electric motors 23, as best shown in Figs. 2 and 14. Desirably, the mandrel speed can be adjusted. A vertical bore 83 through the spindle 70 provides communication between a coolant supply line 84 and the coolant distributing pipe 64 in the mandrel 22. The forming of the workpiece 50 on the mandrel 22 is effected by a pair of forming rolls 85 which utilize rolling action to roll and shear the flat workpiece 50 to conform to the shape of the mandrel 22 and with the desired wall thickness, but which operate without the sliding action inherent in conventional machines of this general type. It is important, as hereinafter discussed in detail, that the axis of each roll 85 be at an acute angle to the surface being formed, preferably close to perpendicular to this surface, rather than parallel with this surface as with the conventional form of forming machine of this character. The working surface 86 of each forming roll is preferably of frusto-conical form and this working face can enlarge toward the mandrel 22 and terminate in an enlarged circular edge 87 as shown in Figs. 1, 9, 10 and 12. The end face 88 can also be of frusto-conical form to bulge toward the mandrel 22 but it is important that this end face has merely a polishing contact with the workpiece 50, the action of the rolls being wholly a function of the rolling action of their working faces 86 and the rolling action of the edges 87 provided at the ends of these working faces adjacent the mandrel 22 and a polishing action of a portion of the end faces 88.

Alternatively, as illustrated in Fig. 13, each roll 85*a* can have its frusto-conical working face 86*a* diminish toward the mandrel 22 so that its edge 87*a* is at the minimum diameter end of the working face 86*a*. Each roll 85*a* is shown as having a slightly bulging end face 88*a*.

With either form it is important that the rolling work area of the working face 86, 86*a* of each roll 85 or 85*a* be at an acute angle to and close to perpendicular to the surface being generated on the mandrel 22 so that the action of these working faces is essentially a rolling action.

The rolls 85 or 85*a* are freely revolvable and since heavy pressures are involved, these rolls are each preferably mounted on a spindle 93 journalled in a bore 94 extending through a bearing housing or casting 95 as best illustrated in Fig. 10. As best shown in Figs. 8, 9 and 10, the central part of this bearing housing or casting 95 is tubular to provide the bore 94, but this tubular central part is provided with opposite wings or arms 96 each of which is of segmental or arcuate form in a plane parallel with the axis of the bore 94, as best shown in Fig. 9.

The spindle 93 is preferably tubular and has an enlarged head 98 provided with a frusto-conical face 99 which diminishes toward the mandrel 22. This frusto-conical face 99 engages a complementary frusto-conical internal seat 100 in the roll 85. The opposite side of the roll 85, that is, the side facing the mandrel 22, is provided with a recessed conical seat 101 in which is fitted the conforming head 102 of a tie bolt 104. The shank of this tie bolt extends through the bore of the spindle 93 and its nut 105 tightens against the end of the spindle 93 opposite its head 98. The tie bolt is provided with an axial through bore 106 through which a coolant or cutting oil supply pipe 108 extends, this pipe being mounted on a bracket 108' and terminating in a nozzle 109 which plays cooling fluid against the corresponding roll 85 toward its shearing edge 87.

The bearing housing or casting carrying the spindle 93 is shown as having a portion 110 of reduced diameter to provide an abutment for one race 111 of a pair of thrust bearings 112 having a common race 113 and an end race 114 opposite the race 111. The common race 113 engages the spindle 93 and is held between two spacer sleeves 115 and 116, the former of which abuts against an annular shoulder formed on the stem of the spindle 93 and the latter of which is fixed against the inside race of a pair of radial roller bearings 118, the opposite end of this inside race bearing against a nut 119 screwed on the end of the spindle 93 remote from its head 98. The thrust of the race 114 of the thrust bearings 112 is against an externally threaded bushing 120 screwed into the corresponding internally threaded end of the bore 94. The outer race of each radial roller bearing 118 is fitted in this externally threaded bushing. Another pair of radial roller bearings 121 are interposed between the opposite or head end of the spindle 93 and the bore 94 of the bearing housing or casting 95.

It will be seen that each forming roll 85 or 85*a* can be readily removed and replaced as it becomes worn or if a different shape of forming roll should become desirable to form a different shaped product. Thus by removing the nut 105, the tie bolt 104 can be removed from the spindle 93 so that the forming roll 85 can readily be removed and replaced. In such replacement, the forming roll is wedged onto the conical faces 99 and 101 of the spindle 93 and head of the tie bolt 104, respectively, so that the forming roll is tightly secured to the end of the spindle in accurately centered relation therewith. Further, each end of this spindle is journalled in a pair of radial roller bearings 121 and 118 and is held against end thrust by the pair of central thrust roller bearings 112.

Each of the forming rolls 85 is mounted to be turned, while in operation, about its working tip, this being the lower extremity of the edge 87 of the forming roll. For this purpose each wing or arm 96 of the bearing housing

or casting 95 is provided with quarter cylindrical outer and inner bearings faces 125 and 126 each of which is concentric with the working tip of the edge 87. The segmental cylindrical bearing faces 125 of the two wings or arms 96 of each bearing housing or casting 95 mate with a pair of spaced segmental cylindrical bearing faces 128 provided in the underside of an adjustable holder 129, this adjustable holder 129 being mounted for adjustment generally parallel or concentric with the axis, when horizontal, of its forming roll 85 as hereinafter described in greater detail. The quarter cylindrical bearing faces 125 of the bearing housing or casting 95 for each forming roll 85 is held in engagement with its companion bearing face 128 of the corresponding adjustable holder 129 by an arcuate retainer 130 which is secured in any suitable manner (not shown) to the adjustable holder 129 to project under the corresponding bearing face 126 in concentric relation therewith. An arcuate wear strip 131 of suitable bearing metal is shown as interposed between each arcuate bearing face 126 and arcuate retainer 130.

To move the bearing housing 95 for the forming rolls 85 along the arcuate bearings 128 and 131, each of the arcuate bearing faces 125 is provided with a central arcuate recess formed to provide a series of transverse gear teeth 135. Each series of gear teeth is engaged by a pinion 136 fast to a shaft 138 driven by a hydromotor 139. It will be seen that each forming roll 85 is provided with two hydromotors 139 which rotate the bearing housing for each roll about the tool tip or lower extremity of the edge 87 of the forming roll.

Each adjustable holder 129 has an arcuate convex upper face 140 which mates with the arcuate concave underface 141 of a reciprocating holder 145. Any suitable means (not shown) can be provided for securing the holders 129 and 145 together so that each adjustable holder 145 can be adjusted about the axis of the arcuate faces 140, 141 and held in any selected position of adjustment. These faces are generally parallel or concentric with the axis of rotation, when horizontal, of the forming rolls 85.

The reciprocating holders 145 are mounted to move horizontally toward and from each other to move the forming rolls 85 toward and from each other. For this purpose each reciprocating holder is provided with a flat horizontal upper face 146 which is slidingly fitted against the flat under face 148 of a bolster 149 and rails 150 are secured by stud bolts 151 to the under face 148 of the bolster 149. As best shown in Fig. 4, each of these rails has a horizontal flange 152 extending under and supporting the corresponding edge of the corresponding reciprocating holder 145 and on which flanges 152 the reciprocating holder slides. As best shown in Fig. 5, these pairs of rails are parallel and in line with each other so that the reciprocating holders 145 are capable of reciprocating toward and from each other.

To move these reciprocating holders 145 toward and from each other each of these holders is provided in its upper side with a transverse square channel 155 in which are placed a pair of square nuts 156 which are threaded on screws 158. These screws are arranged parallel with the rails 150 and extend through horizontal oversize through bores 158' in the reciprocating holders 145. Each screw 158 is common to the two reciprocating holders 145 and its opposite ends are reversely threaded with a nut 156 at each end so that upon turning the screws 158 in one direction the reciprocating holders 145 are moved toward each other, and upon turning these screws in the other direction these reciprocating holders are moved away from each other.

To so turn the screws 158, pinion 159 is fast to one end of each shaft and meshes with a common gear 160 as best shown in Figs. 4, 5 and 6. This common gear 160 in turn is fast to a shaft 161 journalled through bearings 162 in the bolster 149 and carrying a pinion 163 as best shown in Fig. 6. As shown in Figs. 3 and 6, this pinion 163 meshes with a rack 164 which is fast to a sliding cylinder 165. Externally this cylinder is rectangular in cross section and is provided with outwardly projecting longitudinally extending flanges 166 each of which is supported by an L-shaped rail 169 secured to the under side of the bolster 149 and along which rails 169 the cylinder 165 reciprocates. A piston 170 is arranged in the sliding cylinder 165 and piston rods 171 and 172 extend from opposite ends of the piston 170 through end heads 173 for the sliding piston. These piston rods 171, 172 and their piston 170 are stationary and are fixed to arms 174 extending from the bolster 149. Each is also provided with a bore 174', 174'' which communicates with the corresponding end of the cylinder 165, these bores connecting with control lines as hereinafter described.

While the double ended screws 158 are satisfactory for accurate and fine adjustment of the spacing of the reciprocating holders 145 for the forming rolls 85, it is important that these screws carry only a small fraction of the load impressed against the workpiece 50 by the forming rolls 85. To this end four auxiliary cylinders indicated generally at 175 are provided, one of these auxiliary cylinders being arranged alongside each end of each screw 158.

As best shown in Figs. 5 and 6, each cylinder 175 is mounted in a corresponding reciprocating holder 145 alongside the end of a companion screw 158. The inner end 176 of each cylinder 175 is blind and its piston 178 has a piston rod 179 sliding in a stuffing box 180 at the outer end of each cylinder. Each piston rod has a conduit 181 communicating with the inner end of its cylinder and another conduit 182 communicating with the outer end of its cylinder. The outer end of each piston rod 179 is suitably secured, as indicated at 183, to the underside of the bolster 149.

To relieve the pressure of the flat upper face 146 of each reciprocating holder 145 against the under face 148 of the bolster 149, a hydraulic pad or plunger 185 is arranged in each reciprocating holder 145 to be projected upwardly. As best shown in Fig. 7, each pad or plunger 185 has an enlarged upper head 186 providing an enlarged upper face and has a reduced vertical stem 188 working in a cylinder 189 in the corresponding reciprocating holder 145 and opening toward the top face 146 of this holder. Pressurized fluid is applied to and relieved from each cylinder 189 through a line 190.

The bolster 149 is shown as clamped at its opposite sides to the bottom plate 191 of the movable platen 31 by a plurality of clamping blocks 192 held in clamping relation with these parts by stud bolts 193. It will therefore be seen that this vertically movable platen 31 provides the vertical movement of the forming rolls 85; that the reciprocating holders 145 provide the horizontal movement of these rolls toward and from each other; that the bearing housings 95 with their arcuate wings or arms 96 provide movement of each roll 85 about the lower or working tip of the edge 87 of each roll to adjust the angle of attack of each roll; and that the adjustment of the adjustable holders permits of adjusting the forming rolls horizontally in directions transversely of their axes of rotation.

The two forming rolls 85 are constrained to follow the shape of the mandrel 22 and for this purpose a template in the form of a flat vertical plate 195 is removably supported by brackets 196 and 198 at one side of the machine. This plate has an operative pattern edge 199 traversed by the finger 200 of a tracer 201. This tracer 201 is mounted on the cylinder body 165 to move along horizontal rods 202 carried by brackets 203 which project from the movable bolster 149. As shown in Fig. 14,

the movement of the tracer **201** and its finger **200** along the edge **199** of the template **195** is transmitted as an electric signal through lines **204** to a control box **205** and through lines **206** to an electrical amplifier **208**. The electronic tracer control used in the machine is analogous in its nature.

The vertical movement of the tracer finger is amplified and transmitted as a signal through lines **209** to a vertical electrical controller **210** which actuates and controls a reversible motor **211**. This motor drives a pump **212** which has a branched line **213** connected with the pull-back cylinders **33** and another branched line **214** with the vertical ram cylinders **30**. The branched line **214** also connects with the conduits **182** leading, as previously described, to the outer or stuffing box ends of the four horizontal cylinders **175** which serve to relieve pressure on the four screws **158** which position the forming rolls **85** with reference to the mandrel **22** and workpiece **50** contained thereon. The branched line **214** also connects with the conduits **190** leading, as previously described, to the cylinders **189**, the pads or plungers **185** of which serve to relieve the flat upper face **146** of each reciprocating holder **145** against the under face **148** of the bolster **149**.

The horizontal movement of the tracer **200** is translated into an electrical signal and as amplified in the amplifier **208** is transmitted through lines **215** to a controller **216** for a pump **217** driven by an electric motor **218**. One line **219** from this pump **217** leads to one end of the sliding cylinder **165**, this being the left hand end as viewed in Figs. 3 and 14, so as to drive this cylinder to the left in response to preponderating pressure introduced from the line **219**. Another line **219'** from the pump **217** leads to the other or right hand end of the sliding cylinder **165**. As the sliding cylinder **165** moves to the right through its rack **164** it drives the pinion **163**, shaft **161** and gear **160** (Fig. 3) to rotate the pinions **159** and double ended screws **158** (Fig. 4) in that direction to advance the reciprocating holders **145** toward each other. Since the reciprocating holders **145** carry the adjustable holders **129** which in turn carry the forming rolls **85**, this movement of the reciprocating holders **145** toward each other causes the forming rolls **85** to approach each other to effect a corresponding shaping of the workpiece **50** on the mandrel **22**. Since this horizontal movement of these forming rolls **85** toward each other, as well as the movement of these rolls away from each other is under control of the tracer finger **200** and the amplified electrical signal generated thereby through the controller **216** controlling the direction and degree of pressure provided by the pump **217** in the lines **219** and **219'**, respectively, it will be seen that the horizontal movement of the tracer finger **200** in following the template **195** determines the shaping of the workpiece **50** against the rotating mandrel **22**.

A second hydraulic circuit has a supply pump **220** driven by an electric motor **221** and supplying hydraulic fluid through a line **222** under pressure to a flow control valve **223** which can be a manually operated solenoid valve **224**. One line **225** from this manually operated control valve **224** connects with the top of the tailstock cylinder **45**. Another line **226** connects with the bottom of this tailstock cylinder **45** and by manual operation of the control valve **224**, the tailstock **49** can be brought into clamping engagement with the workpiece **50**.

A branch line **228** connects the pump **220** with a flow control valve **229** which can be under manual or automatic control. One branched line **230** from this manual or automatic flow control valve **229** connects with one side of each of the four hydromotors **139** which, as previously described, vertically adjust the angular positions of the axes of the forming rolls with reference to the horizontal. Another branched line **231** connects the flow control valve **229** with the other side of each of the four hydromotors **139** and by operation of the flow control valve **229** the four hydromotors **139** can be energized to adjust the axes of the two forming rolls **85** vertically to any desired angularity with reference to the horizontal about transverse axes intersecting the lower extremities of the edges **87** of these forming rolls.

A branch line **233** connects the pump **220** with a solenoid flow control valve **234** which is under control of a series of pressure switches as hereinafter described. One line **235** from this solenoid flow control valve connects with one end of a cylinder **236** and another line **238** from this solenoid flow control valve connects with the opposite end of this cylinder **236**. Hydraulic fluid controlled by the solenoid control valve **234** can be supplied from **238**. The cylinder **236** contains a piston **239** driving a piston rod **240** and rack **241**. The rack drives the pinion **242** of a pressure relief valve **243**. Through the branched line **244** this pressure relief valve controls the back pressure in the blind ends of the four cylinders **175** and hence control the effect of the pistons **178** in relieving the horizontal back pressure of the forming rolls **85** against the workpiece.

The pressure required to turn the screw **158** to move the forming rolls **85** toward each other determines the back pressure maintained in the blind ends of the cylinders **175** which relieve these screws thereby providing a self-compensating load relieving device in which the degree of relief provided is proportional to the horizontal load against the forming rolls **85** and to reduce the friction and load on the screws **158** to a minimum constant. To this end a progressive series of pressure switches **250**, **251**, **252** are responsive to progressive changes in the pressure in the left hand end of the sliding cylinder **165** and hence to the horizontal pressure being exerted by the screws **158** through the forming rolls **85** against the workpiece **50**. Through a branched electrical line **253** these solenoid switches control the solenoid flow control valve **234** to adjust the back pressure in the blind ends of the cylinders **175** to a corresponding value.

Operation

To illustrate the operation of the apparatus, the revolving mandrel **22** (Fig. 1) is shown as being of simple frusto-conical form, and it is assumed that the product is to be of similar frusto-conical form with a uniform peripheral wall thickness. However, any circular hollow shape such as cones, semispheres or combinations of both can be produced. To this end the operative edge **199** of the template **195** (Fig. 2) is in the form of a simple straight slope conforming to the taper of the peripheral wall of the mandrel **22**. It will be assumed that the frusto-conical product is to be produced without chips or shavings to have a smooth finish and increased physical properties without using alloy stock or heat treatment for this purpose and that the product is to be produced faster than any conventional machine with small power consumption and a wall thickness to be held to very close tolerance.

The operator places the metal blank **50** (Fig. 1), which may be of steel having a thickness in the order of 1½ inches, with its center on top of the mandrel **22** and starts the operation of the press. This can be done (Fig. 14) by manually operating the solenoid flow control valve **224** to admit hydraulic fluid under pressure from the pump **220** through the line **225** into the top of the tailstock clamping cylinder **45** and relieving fluid from under the piston **46** therein through the line **226**. This forces down the piston **46**, and through the thrust bearing **55** (Fig. 9) and tailstock holder **51** forces the tailstock **49** down to clamp the workpiece **50** against the flat top of the mandrel **22** as shown in Fig. 9.

The operator then either manually or automatically energizes the two mandrel driving motors **23** (Fig. 1). Through their common shaft **82** these motors drive a worm **81** (Fig. 11) and worm wheel **80**, the latter driving the vertical spindle **70** in its bearings **71**, **75** and **77** and hence the face plate or table **62** fast to the spindle

70. Since the mandrel 22 is fast to this table 62, the mandrel is rotated about its vertical axis.

Desirably, the speed of rotation of the mandrel 22 is adjustable by control of the motors 23 which are preferably infinitely adjustable for this purpose. In order to keep the rolling speed constant on increasing diameters of the workpiece 50 being formed, the mandrel r.p.m. is desirably controlled. This can be effected manually or by any suitable automatic control (not shown). However, a constant rolling speed on increased diameters at a constant downward forming roll feed per unit of time would produce an increased lead on the helix as the forming rolls approach the bottom of the cone resulting in objectionable variation of surface finish. This can be avoided by providing a constant downward feed of the forming rolls per revolution of the mandrel. This can be accomplished by adjusting the vertical and horizontal feeds of the forming rolls as through a tachometer, but since these details are incidental to the main objectives of the invention, these details have not been illustrated.

The tailpiece 49 which holds the workpiece 50 clamped against the mandrel 22 does not interfere with this rotation of the mandrel since the holder 51 for this tailpiece revolves in its bearings 52 and 55 (Fig. 9) and the downward pressure of the piston 46 in the tailpiece clamping cylinder 45 is exerted downwardly through the thrust bearing 56.

The workpiece 50 so clamped is now ready for rolling and shear deformation by the forming rolls 85. To initiate movement of these forming rolls toward opposite sides of the rotating mandrel 22 and the workpiece thereon the operator control box (Fig. 14) is automatically or manually set to render the tracer 201 with its tracer finger 200 operative. The electric signal generated by the tracer 201 is amplified in 208 and the signal which is responsive to the vertical component of the tracer finger is transmitted through the lines 209 to the control 210 for the reversible motor 211 of a pump 212. In the elevated position of the tracer 201, as illustrated in Fig. 2, this vertical component of the signal drives the reversible motor and pump 211, 212 (Fig. 14) to produce hydraulic pressure in the line 214 and to withdraw hydraulic fluid from the line 213. Accordingly, the main rams 32 are moved downwardly in the ram cylinders 30 and these rams move the moving platen 31 carried thereby downwardly, this platen being guided by the main columns 25 of the press frame (Fig. 1). Through the bolster 149 fixed to the bottom of the moving platen 31, the two reciprocating holders 145 mounted on the underside of this bolster (Fig. 4) and the adjustable holders 129 severally secured to these reciprocating holders, this downward movement is transmitted to the pair of opposing forming rolls 85 carried by these adjustable holders 129 (Fig. 9). As illustrated in Fig. 10, each forming roll 85 is carried by a freely rotatable spindle 93 journalled in the corresponding adjustable holder (Fig. 9) so that the forming rolls 85 are free to rotate.

As the two forming rolls 85 move down they contact the revolving workpiece 50 with their edges 87 as shown in Fig. 9 and accordingly, the rolls rotate under the influence of the workpiece 50. As the rolls 85 continue to move downwardly their edges 87 cut into the workpiece and the rolling work face 86 displaces the adjacent metal to produce the desired form. To utilize this combined rolling and shearing action to shape the workpiece 50, the forming rolls are constrained to move horizontally in conformity with the shape of the working edge 199 of the template 195 as follows:

The tracer 201 is mounted on the moving platen 31 to move downwardly with this moving platen. As the tracer finger follows the template edge 199 it is moved horizontally by this edge and the signal generated by this tracer finger movement is transmitted through the lines 215 to the control 216 for a pump 217. When the template edge 199 (Fig. 2) biases the tracer finger 201 horizontally (and hence calling for spreading movement of the two forming rolls 85) the controller 216 (Fig. 14) adjusts the pump 217 to apply pressure to, say, the right hand side of the sliding cylinder 165 through the line 219' and to withdraw hydraulic fluid through line 219 from the left hand side of this cylinder. Since the piston 170 (Fig. 3) is fixed between the spaced brackets 174 on the bolster 149, this unbalanced pressure in the sliding cylinder 165 moves this cylinder to the left, as viewed in Figs. 3 and 14, along its rails 169 thereby to move the rack 164 in a corresponding direction. This rotates the pinion 163, shaft 161 and large common gear 160, and this common gear 160 (Fig. 4) rotates the pinions 159 fast to the two double ended screws 158.

This rotation of these double ended screws (Fig. 5), through the four square nuts 156 at their opposite ends, and which are held against turning, operates to spread these pairs of nuts away from one another. Since each pair of these square nuts 156 are confined in the channels 155 of the two reciprocating holders 145, these holders are moved apart, following the guide rails 150 which slidably secure these reciprocating holders 145 to the underside of the bolster 149 as illustrated in Figs. 4, 5 and 6. Since the forming rolls 85 are carried by these reciprocating holders 145 through the medium of the adjustable holders 129 (Fig. 4) and the spindle mountings for these forming rolls (Figs. 9 and 10) the forming rolls are moved apart in response to the shape of the template edge 199 (Fig. 2) and to produce a corresponding side wall shape in the workpiece 50 as the forming rolls descend along the peripheral face of the mandrel 22.

It will be seen that rotating the double ended screws 158 in opposite directions serves to move the forming rolls 85 toward and from each other and that these screws insure concentric movement of the forming rolls with reference to the vertical axis of the mandrel 22.

Heavy horizontal forces are imposed by the workpiece against the two forming rolls 85 tending to spread these rolls and in the absence of a means to relieve these forces, they would all be borne by the double ended screws 158 resulting in excessive friction and work by these screws and corresponding inaccuracy of control. To relieve this condition, the greater part of the heavy horizontal forces imposed by the workpiece against the forming rolls 85 and tending to spread these rolls is borne by the bodies of hydraulic fluid trapped in the blind or opposing ends 176 of the four cylinders (Figs. 5, 6 and 14). Thus spreading pressure on the forming rolls 85 (Fig. 9) exerts spreading pressure on the adjustable holders 129 and the reciprocating holders 145 (Figs. 5 and 6) which carry the adjustable holders 129, these spreading forces being transmitted to the double ended screws 158 except that the greater part of these spreading forces are transmitted through the cylinders 175 fast to the reciprocating holders 145 (Fig. 6) through the body of hydraulic fluid trapped between the blind ends 176 of these cylinders and the stationary pistons 178. Escape of these trapped bodies of hydraulic fluid must be provided, of course, in order to permit spreading of the forming rolls 85 in following the slope of the template edge 199 (Fig. 2) and the rate of escape of these trapped bodies of hydraulic fluid is controlled so that their resistance is proportional to the load imposed against the forming rolls by the workpiece. To this end the series of pressure switches 250, 251 and 252 are disposed in the line 219 leading from the pump 217 to the left hand end of the sliding cylinder 165 as viewed in Figs. 3 and 14. The pressure in this end of this cylinder and the line 219 is proportional to the spreading pressure exerted against the forming rolls 85 by the workpiece 50 and hence these pressure switches 250, 251 and 252 operate in response to the spreading pressure against and the resistance of the forming rolls 85 to this spreading pressure. These pressure switches 250, 251,

252 control the solenoid flow control valve 234 (Fig. 14) to move the piston 239, rack 241 and pinion 242 and adjust the relief valve 243 so that the rate of escape of the hydraulic fluid from the blind ends 176 of the four cylinders 175 is controlled to maintain the friction and load against the screws 158 at a minimum constant. By so relieving these double ended screws, they operate to hold the position of the forming rolls 85 to a very high degree of accuracy.

When the press goes into operation hydraulic fluid is supplied under pressure from the pump 212 and branched line 214 (Fig. 1) to the vertical cylinder 189 (Fig. 7) formed downwardly from the top sliding face 146 of each reciprocating holder 145. This forces upwardly the plunger or ram 185 in each of these cylinders so as to relieve the pressure between the sliding faces 146 and 148. This plunger or ram acts as a jack ram to eliminate the possibility of wedging of the sliding faces 146, 148 and any unfavorable force distribution.

A most important feature of the invention resides in the angularity, in a vertical direction, of the axis of each forming roll 85, it being important that the working part of the peripheral face of each forming roll be close to perpendicular to the surface being generated by the roll, the axis of each roll also being approximately perpendicular to this surface. As shown in Fig. 12, the working part of the peripheral face 86 of the forming roll 85 is at an acute angle to the surface being generated and the axis of rotation of this roll is likewise at an acute included angle. In Fig. 13 the working part of the peripheral face 86*a* of the forming roll 85*a* is at an obtuse angle to the surface being generated whereas the axis of this roll is again at an acute included angle to this surface. In producing forms having different slopes or degree of taper as compared with the cone illustrated, it is necessary that the axis of rotation of the two forming rolls be adjustable. This adjustment is effected as follows:

Manual or automatic operation of the solenoid flow control valve 229 (Fig. 14) supplies hydraulic fluid from the pump 220 and line 228 to the lines 230 or 231 to drive the hydromotors 139 in one direction or the other. This rotates the four shafts 138 and gears 136 (Fig. 9) in a corresponding direction. Through the segmental gear teeth 135, this rotates each bearing housing or casting 95 about a transverse axis intersecting the working tip or zone of its forming roll 85, this bearing housing having arcuate bearing faces 125 and 126 (Fig. 8) slidingly engaging the corresponding supporting bearing faces 128 and 131 for this purpose. Since as shown in Fig. 8 each forming roll has a pair of the hydromotors 139 and since these hydromotors are coupled hydraulically and mechanically, it will be seen that the angular relation between the working parts of the peripheral faces of the forming rolls can readily be adjusted with reference to the particular surface being generated or to any change in the angularity or slope of the product being formed.

The importance of this acute or obtuse angular relation between the working part of the peripheral face of each forming roll is to obtain essentially a rolling action of this face in displacing the metal being sheared from the blank by the edges 87, 87*a* as illustrated in Figs. 12 and 13. In conventional rotary metal forming machines of this character the axis of rotation is arranged generally parallel with the surface being generated and the working face of the roll is an axial end face rather than the peripheral face of the roll. With such use of the end face of the forming roll it is apparent that the deformation of the metal sheared at the working tip or zone of the end face is effected by a sliding action of the end face along the face of the metal being displaced, this resulting in the generation of heat of friction which at the pressures involved is high. In contrast, by the use of the peripheral face of the roll as illustrated in Figs. 12 and 13, it will be seen that the deformation is effected essentially by a pure rolling action and that sliding friction is avoided. The faces 88 of the present forming rolls act as polishing tools in producing a high finish on the product. By reducing heat generation and friction, the work can be performed more rapidly and the product has improved physical properties without the requirement for alloy stock or heat treatment to achieve such physicals. Further by such pure rolling action blanks of greater thickness and size can be processed and for a given amount of work less power is required. Also by such displacement through rolling action greater accuracy can be maintained.

Another important adjustment for each of the two forming rolls 85 is provided, namely about a horizontal axis which is generally parallel or concentric with the axis of rotation, when horizontal, of the forming roll. The axes of rotation of these forming rolls in use, as illustrated in Figs. 12 and 13, is never horizontal and hence this adjustment serves to advance or retract the working areas of the forming rolls with reference to the plane otherwise including the axes of rotation of the two forming rolls and the mandrel, and serves to tilt the forming rolls sidewise, preferably up to 5°, to provide a more efficient tool setting similar to the side relief angle provided in common cutting tools.

This adjustment is achieved by the semicylindrical faces 140 and 141 between the adjustable holders 129 and reciprocating holders 145 for the forming rolls 85 (Fig. 4). These faces are generally parallel or concentric with the axes of rotation of the forming rolls 85, when these axes are horizontal, and hence it will be seen that the rotative positioning of the adjustable holder 129 will permit of providing such relief angle for the forming rolls.

As previously indicated, heat generation is high because of the heavy forces involved, and an important feature of the invention resides in the rapid removal of this heat. A part of this heat can be removed by internally cooling the mandrel 22. Thus, as shown in Fig. 11, cooling liquid supplied from 84 passes through the passage 85 and thence into the central upright pipe 64 in the mandrel 22 from which it issues in a plurality of streams against the inside of the mandrel. The used liquid is slung out from the bottom of the mandrel through the passages 66 against a circular curb 68 which forms a sump from which the liquid can be drained for recooling.

More direct cooling is effected by directing the coolant against the area of the workpiece being deformed. This coolant is supplied from a pipe 108 (Fig. 10) which extends through a central bore in each spindle 93 carrying a forming roll 85. The tips 109 of each pipe discharges a stream of coolant directly toward the working tip of the shearing edge 87 of its forming roll 85.

A further important feature of the invention resides in the ability to rapidly change the forming rolls 85 and at the same time have a spindle mounting which enables them to withstand the heavy working forces. The novel forming roll mounting is illustrated in Fig. 10 from which it will be seen that by removing the nut 105 the tie bolt 104 can be removed from the bore of the spindle 93 to release the forming roll 85 from the conical faces 99 and 101 of the spindle and tie bolt, respectively.

After the product has been formed, the control 210 (Fig. 14), either manually through the operator control box 205, or automatically, is adjusted to reverse the motor 211 so that fluid is exhausted from the ram cylinders 30 through the branched line 214 and fluid is pumped through the branched line 213 into the bottoms of the pullback cylinders 33 to lift the pistons 34 therein and the moving platen 31. At the same time fluid is withdrawn from the cylinders 189 so that the upward pressure of the plungers or jack rams 185 is relieved and the reciprocating holders 145 for the forming rolls are permitted to slide apart normally on their rails 150. At the same time fluid is withdrawn through the conduits 182 and branched lines 214 (Fig. 14) from the stuffing box ends of the four

cylinders **175** thereby to permit of restoring (Fig. 6) the reciprocating holders **145** to any position determined by the double ended screws **158**.

The retrograde movement of these screws **158** is determined by the upward movement of the tracer finger **200** along the edge **199** of the template **195** (Fig. 2), the horizontal signal transmitted through the lines **215** at this time reversing the action of the pump **217** so as to reverse the movement of the sliding cylinder **165** (Fig. 14). This reverses the movement of the rack **164**, pinion **163**, shaft **161**, large gear **160** (Figs. 3 and 4), pinions **159** and double ended screws **158**. This retrograde rotation of these double ended screws **158** (Fig. 5) restores the reciprocating holders **145** to close association with each other as determined by the tracer finger **200** in relation to the upper part of the template **195** (Fig. 2).

This reversal of the action of the pump **217** also actuates the series of progressive switches **250**, **251**, **252** (Fig. 14) to restore the double solenoid flow valve **234**, piston **239**, rack **241**, pinion **242** and pressure relief valve **243** to their starting positions.

The solenoid flow control valve **224** can then be operated automatically or manually to reverse the flow of liquid through the lines **225**, **226** so that fluid is pumped into the lower end of the tailstock clamping cylinder **45** to lift the piston **46** and tailstock **49** (Fig. 1). This permits removal of the finished cone and placement of another blank **50** on the mandrel **22** for another cycle of operation.

From the foregoing it will be seen that the rotary metal forming machine of the present invention accomplishes all of the objectives and has the many advantages enumerated, particularly in deforming the metal into the required shape by a combined rolling and shearing action to produce a product which is superior in point of surface finish, accuracy and physicals, as well as thinner wall thickness if required, more rapidly and with a smaller expenditure of power and development of heat as compared with conventional presses of this character where the deformation is essentially achieved by a combined sliding and shear action.

We claim:

1. A metal forming machine comprising a mandrel rotatable about an axis, means arranged to hold a metal workpiece against an axial end of said mandrel to rotate therewith, a moving press platen arranged to move lengthwise of the axis of said mandrel toward and from said axial end thereof, a pair of forming rolls arranged at opposite sides of said mandrel and each forming roll having an annular working face terminating in an annular edge, a holder for each of said forming rolls, means mounting said holders on said moving platen for reciprocating movement toward and from each other and toward and from said axis of said mandrel, means rotatably supporting each forming roll on its reciprocating holder to engage its said annular working face with a radially protruding part of said workpiece whereby said annular working faces effect displacement of the metal rolled by said edges, and means constraining said reciprocating holders, while said moving platen is moving toward said mandrel, to move away from each other to produce a hollow shape of the desired form from said workpiece by said forming rolls against said mandrel, comprising a double-ended screw having its ends reversely threaded, a nut on each end of said screw, means securing each nut to a corresponding one of said reciprocating holders, a train of gears operatively connecting said screw with a rack, a first hydraulic cylinder and piston arranged to actuate said rack, means responsive to the shape of a template of predetermined form controlling the supply of hydraulic fluid to said cylinder, a second hydraulic cylinder and piston operatively connecting each reciprocating holder with said moving platen and arranged to move the reciprocating holder lengthwise of said screw, and means arranged to introduce hydraulic fluid under pressure into said second cylinders to relieve said screw of a part of the working load tending to spread said forming rolls in displacing the metal of said workpiece.

2. A metal forming machine, comprising a mandrel rotatable about a longitudinal axis, means arranged to hold a metal workpiece against an axial end of said mandrel to rotate therewith, a pair of forming rolls arranged at opposite longitudinal sides of said mandrel, means rotatably supporting each forming roll with one axial end face opposing said mandrel and with the axis of the roll extending toward the axis of said mandrel in a direction generally perpendicular to the surface to be generated by the forming roll, means moving said forming roll supporting means lengthwise of the axis of said mandrel with the forming rolls in contact with said workpiece, and means constraining the roll supporting means of both rolls, while so moving lengthwise of the axis of the mandrel, to move away from each other to produce, with said mandrel, a hollow shape of the desired form, said axial end face terminating in a peripheral cutting edge which bounds said end face and said peripheral cutting edge also forming one end boundary for a conical working face which forms and has rolling contact with a complementary conical face on the portion of the metal workpiece projecting outwardly from said surface to be generated and which conical working face displaces said outwardly projecting portion of said metal lengthwise of said axis of said mandrel away from said one axial end of said mandrel.

3. A metal forming machine as set forth in claim 2 wherein said one axial end face of at least one of said forming rolls bulges axially from said peripheral cutting edge and acts to polish the external surface of the workpiece.

4. A metal forming machine as set forth in claim 2 wherein said conical working face enlarges to said peripheral edge forming one end boundary thereof.

5. A metal forming machine as set forth in claim 2 wherein said conical working face diminishes to said peripheral edge forming one end boundary thereof.

6. A metal forming machine as set forth in claim 1 wherein means are provided for regulating the amount of said pressure of said hydraulic fluid into said second hydraulic cylinders connecting said reciprocating holders with said moving platen, to correspond to said working load.

7. A metal forming machine as set forth in claim 6 wherein said regulating means comprises a progressive series of pressure switches responsive to pressure changes in the hydraulic cylinder actuating said rack.

8. A metal forming machine as set forth in claim 7 wherein a flow control valve is controlled by said progressive series of switches, wherein a relief valve is connected to relieve fluid from one end of said cylinders connecting said reciprocating holders with said moving platen, and wherein means actuated by said flow control valve regulate the rate of discharge of fluid through said relief valve.

9. A metal forming machine as set forth in claim 1 wherein a hydraulic piston and cylinder is operatively interposed between each reciprocating holder and moving platen and is arranged to bias one end of the reciprocating holder away from the moving platen to avoid wedging of the reciprocating holders against said moving platen under unfavorable force distribution.

10. A metal forming machine as set forth in claim 9 wherein each of said last hydraulic cylinders and pistons is secured to the corresponding reciprocating holder with the piston opposing and arranged to slidably engage said moving platen, and wherein means supply fluid under pressure to said last hydraulic cylinders and pistons contemporaneously with said movement of said moving platen toward said mandrel.

11. A metal forming machine as set forth in claim 2 wherein said means rotatably supporting each forming

roll includes an adjustable holder for the forming roll journalled to swing about an axis extending generally parallel with the line of movement of said forming rolls away from each other, and means for holding said adjustable holder in any desired position.

12. A metal forming machine as set forth in claim 2 wherein said means rotatably supporting each forming roll includes an adjustable holder for the forming roll journalled to swing about an axis generally perpendicular to said axis of said mandrel, and means for holding said adjustable holder in any desired position.

13. A metal forming machine, comprising a mandrel rotatable about a longitudinal axis, means arranged to hold a metal workpiece against an axial end of said mandrel to rotate therewith, a pair of forming rolls arranged at opposite longitudinal sides of said mandrel, a spindle fast to each of said forming rolls, a bearing housing for each spindle, means rotatably supporting each spindle in a corresponding bearing housing with an axial end face of its forming roll opposing said mandrel and with the axis of the roll extending toward the axis of the mandrel in a direction generally perpendicular to the surface to be generated by the forming roll, said axial end face terminating in a peripheral cutting edge which bounds said face and said peripheral cutting edge also forming one boundary for a conical working face which has rolling contact with a portion of the metal workpiece projecting outwardly from said surface to be generated, a holder for each bearing housing, each bearing housing being journalled on its holder to swing about an axis substantially perpendicular both to said axis of said mandrel and to said axis of said forming roll and substantially intersecting the working point of its peripheral cutting edge, means moving said holders lengthwise of the axis of said mandrel with the forming rolls in contact with said workpiece, and means constraining said holders of both rolls, while so moving lengthwise of the mandrel, to move away from each other to produce, with said mandrel, a hollow shape of the desired form.

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