Nov. 4, 1969 G. C. WHITNEY, JR., ET AL 3,475,938

APPARATUS FOR BENDING

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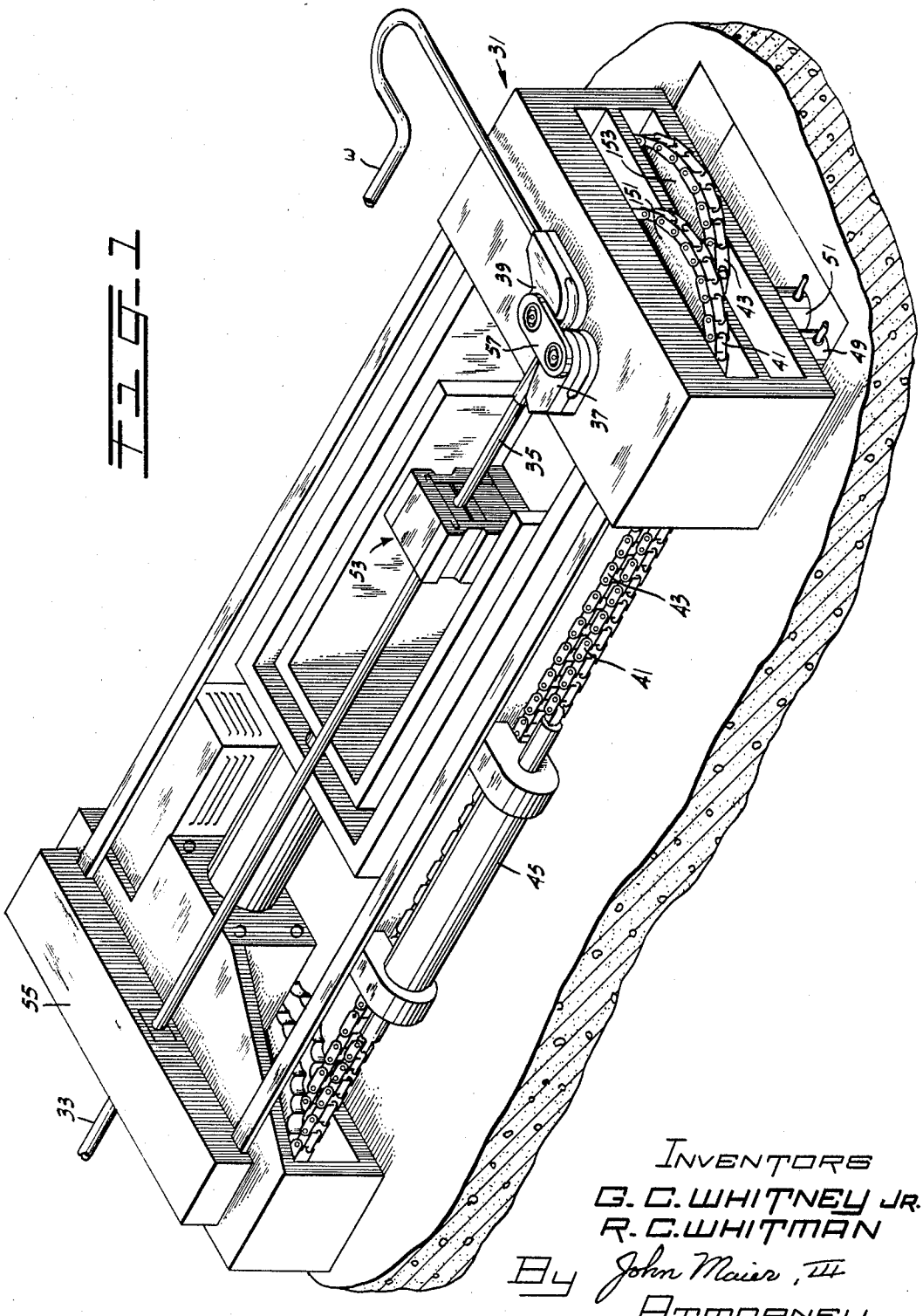
FIG. 1



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By John Maier, III
ATTORNEY

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APPARATUS FOR BENDING

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FIG. 2

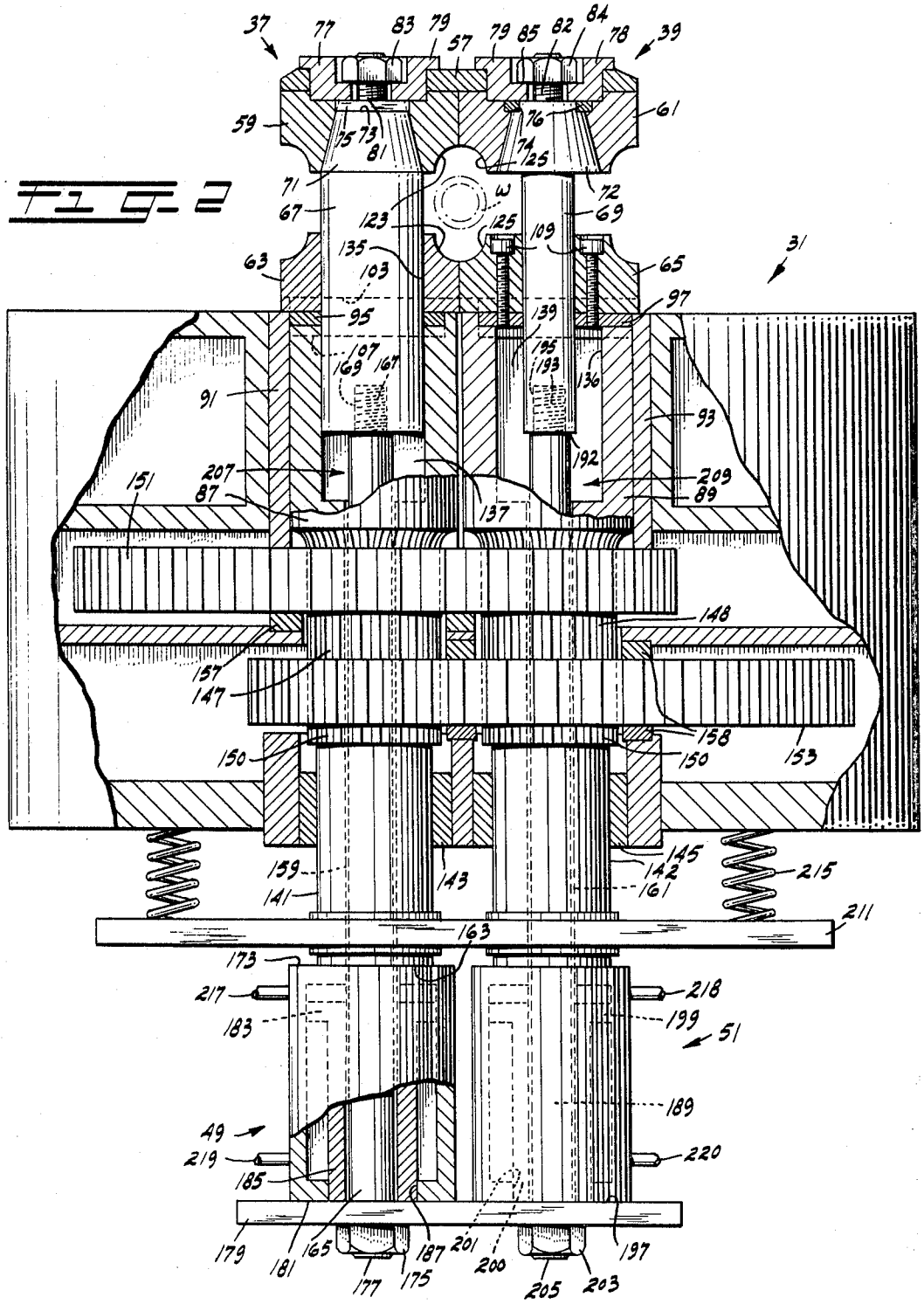

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FIG 3

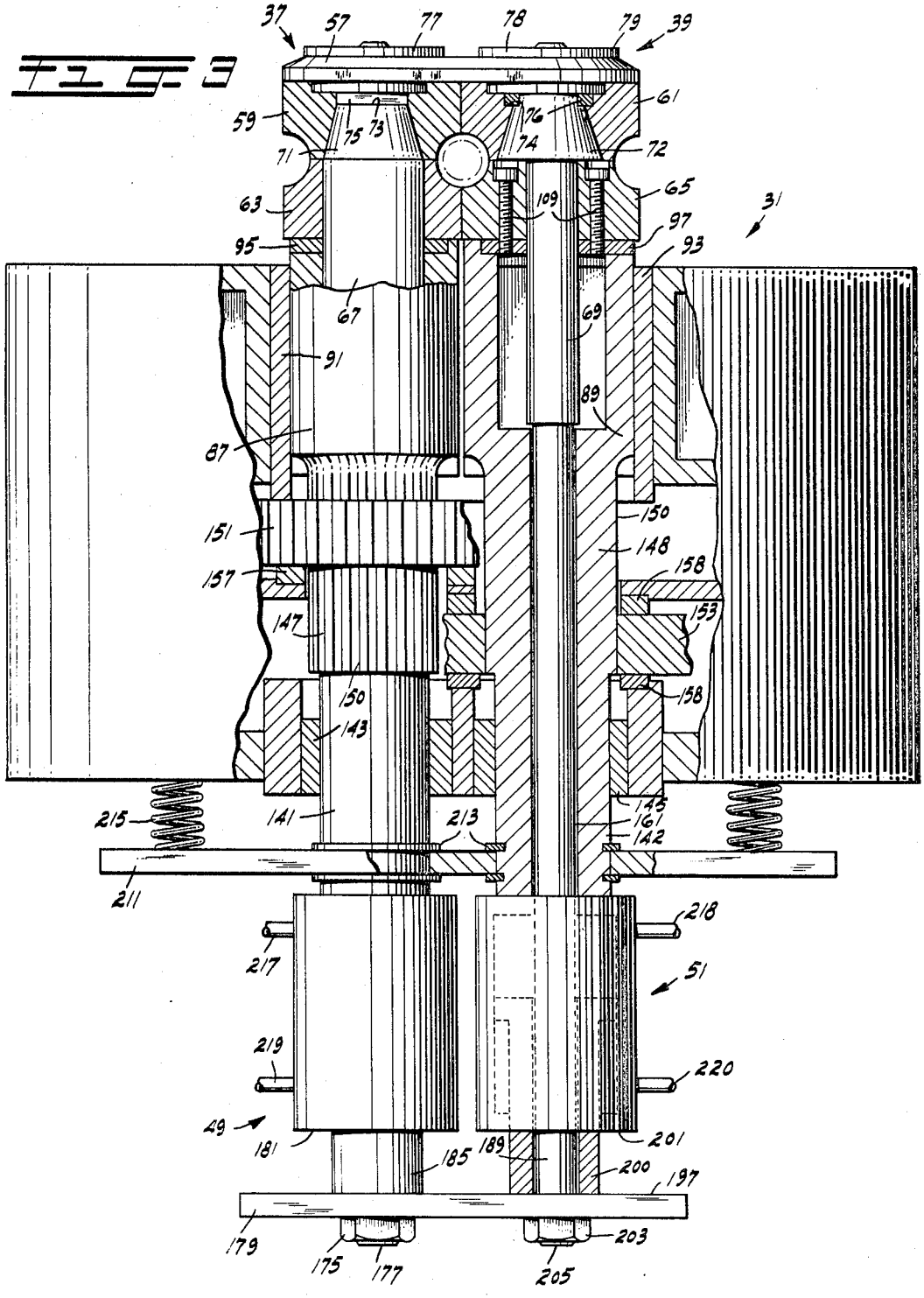
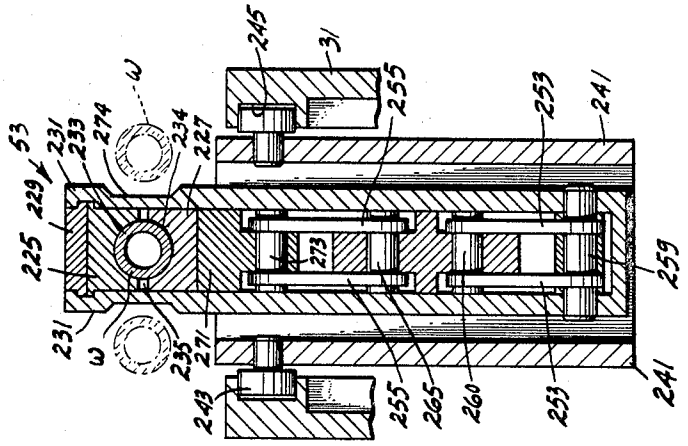


FIG. 5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31
W
255
253
241
53
231
233
274
234
227
229
225
273
259
231
W
235
271
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255
265
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253
241

FIG. 4

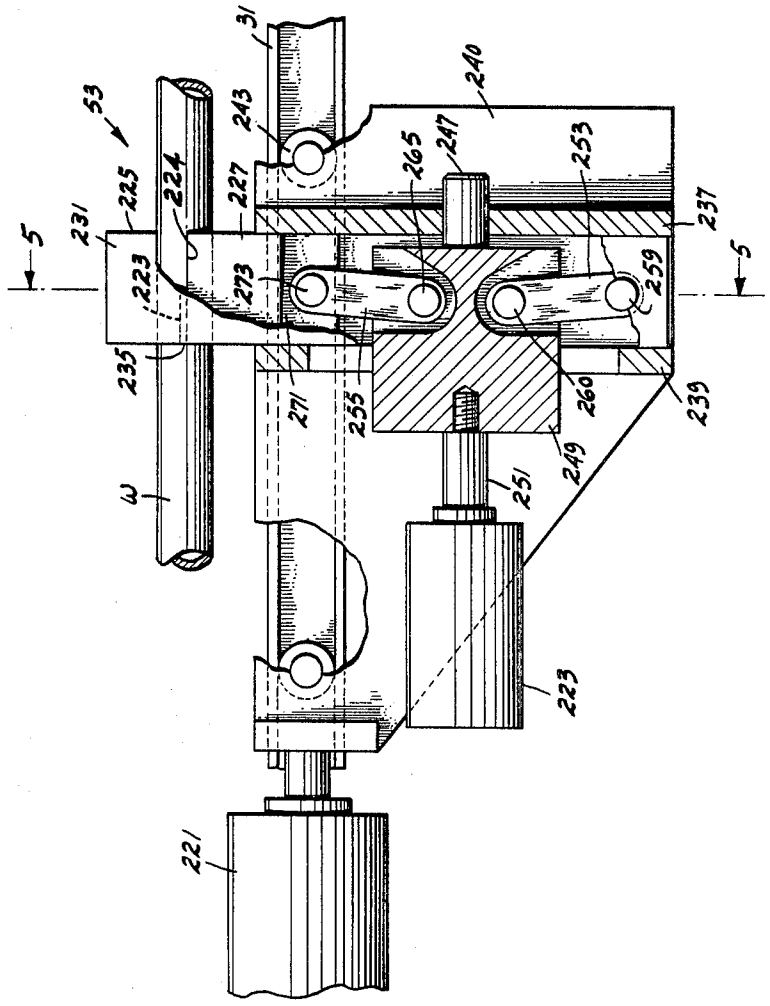
31
240
53
243
247
265
253
225
224
227
237
231
5
5
223
273
259
235
271
255
260
239
249
W
251
223
221

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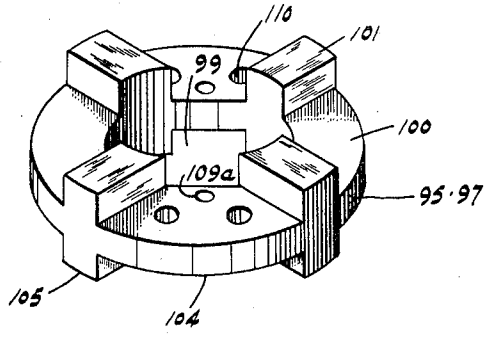
FIG. 7



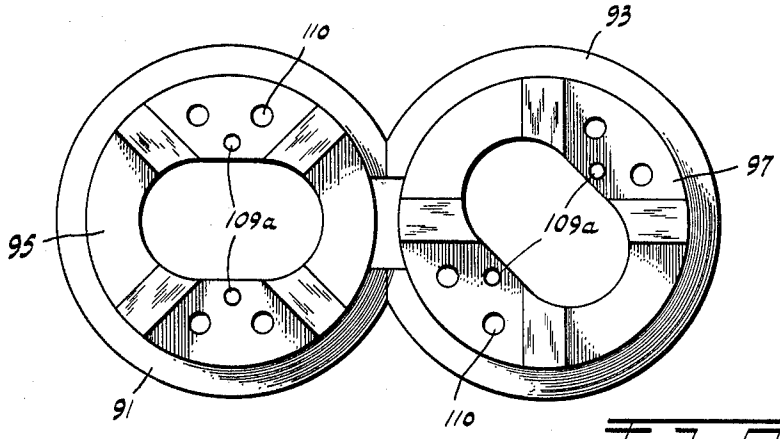


FIG. 6

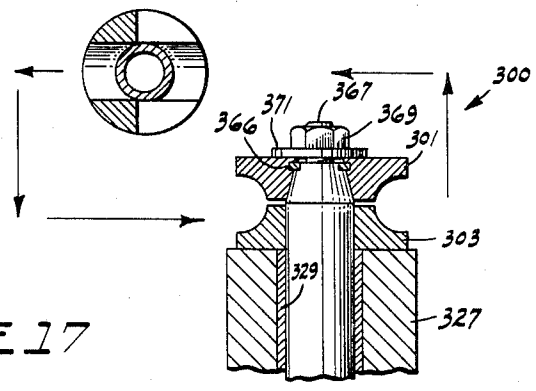


FIG. 17

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FIG. 15

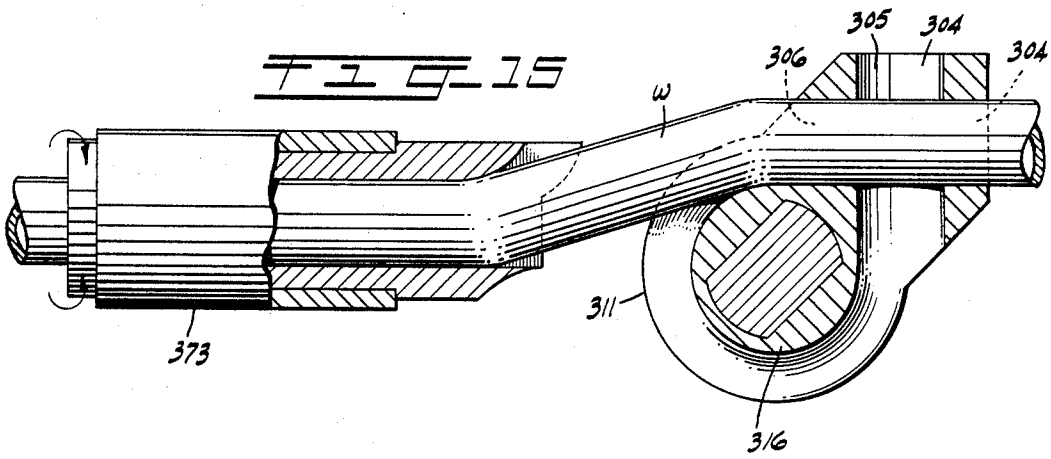

FIG. 16

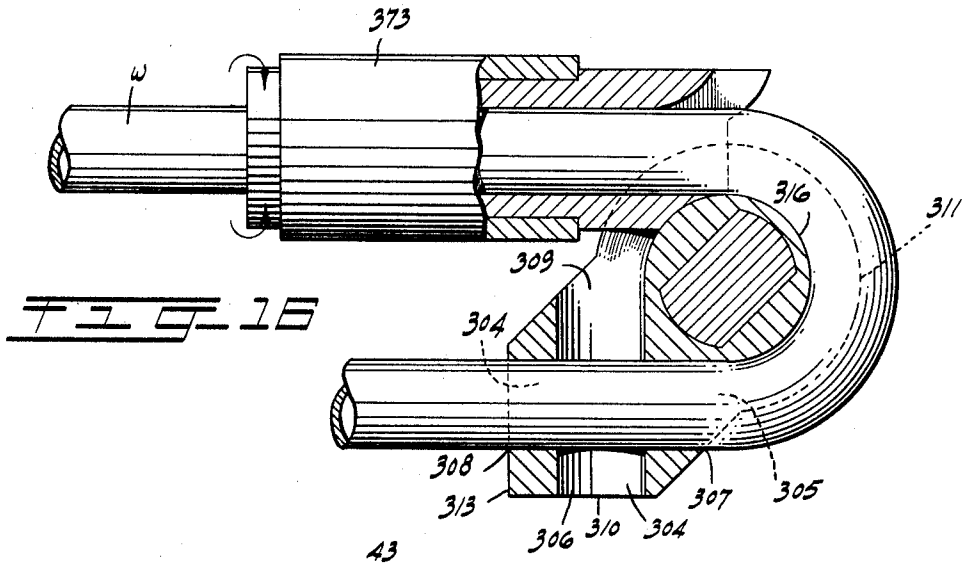

FIG. 8

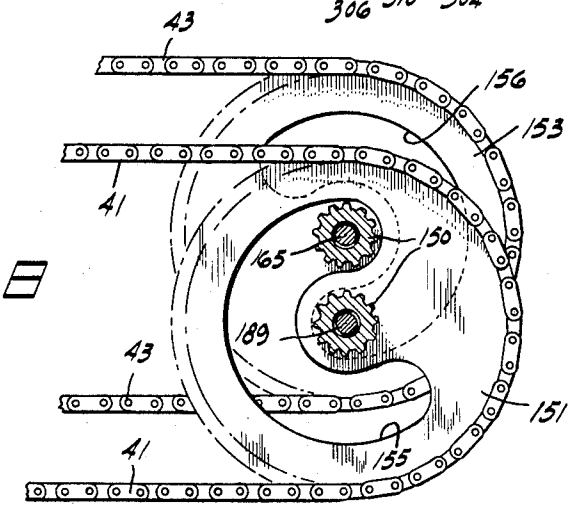

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FIG. 9

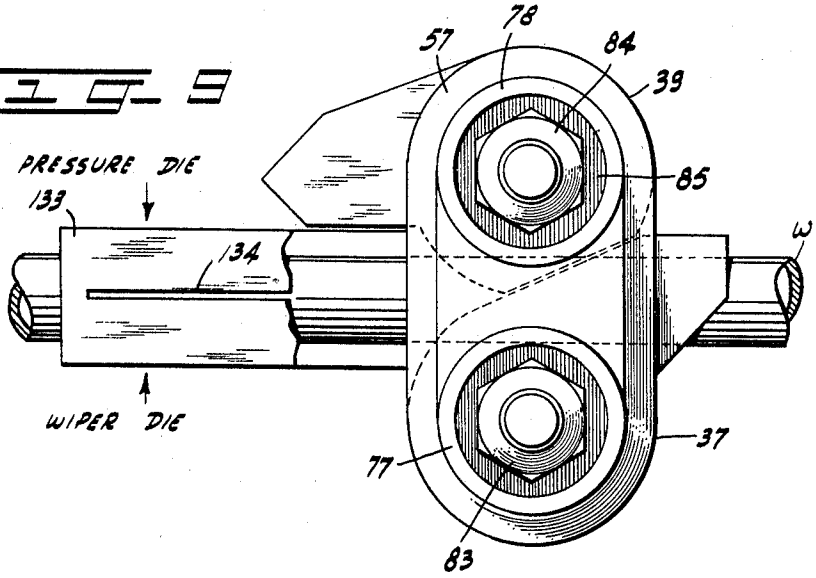


FIG. 10

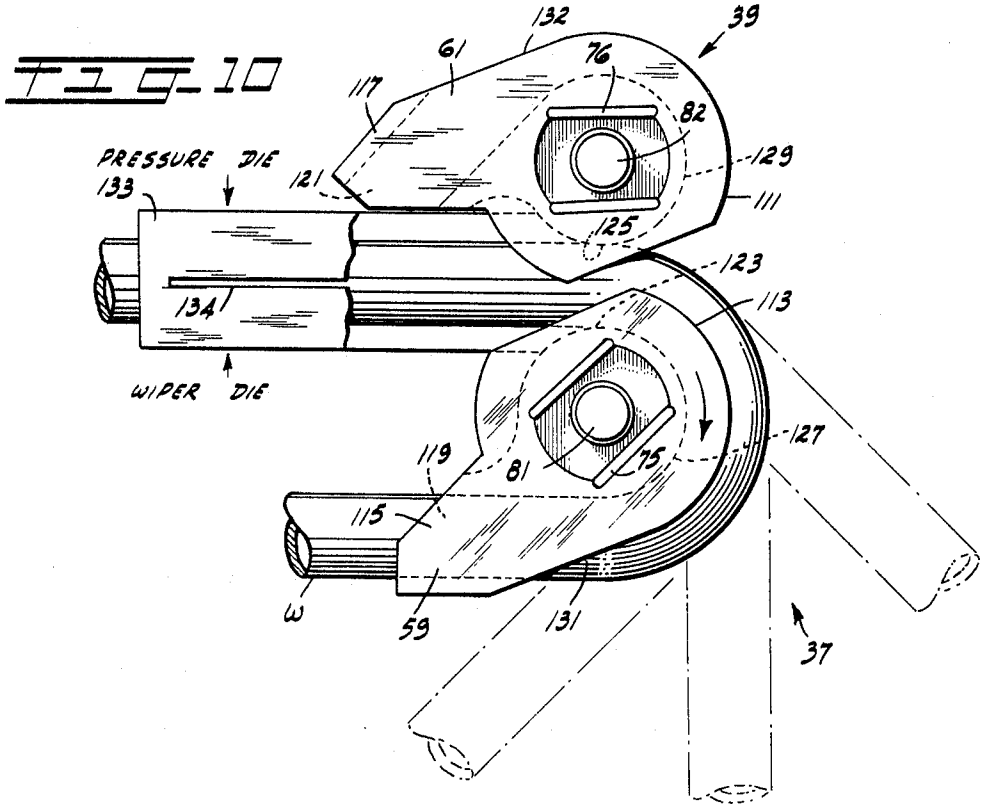


FIG. 11

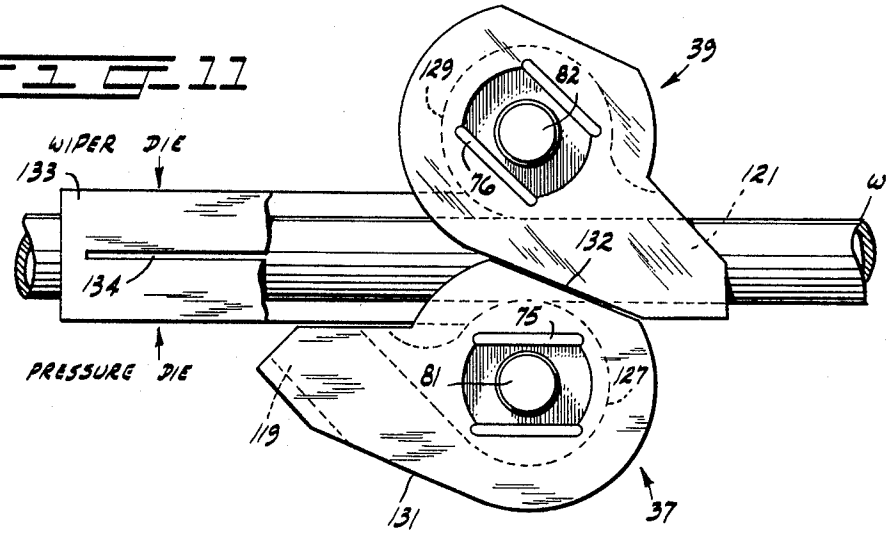
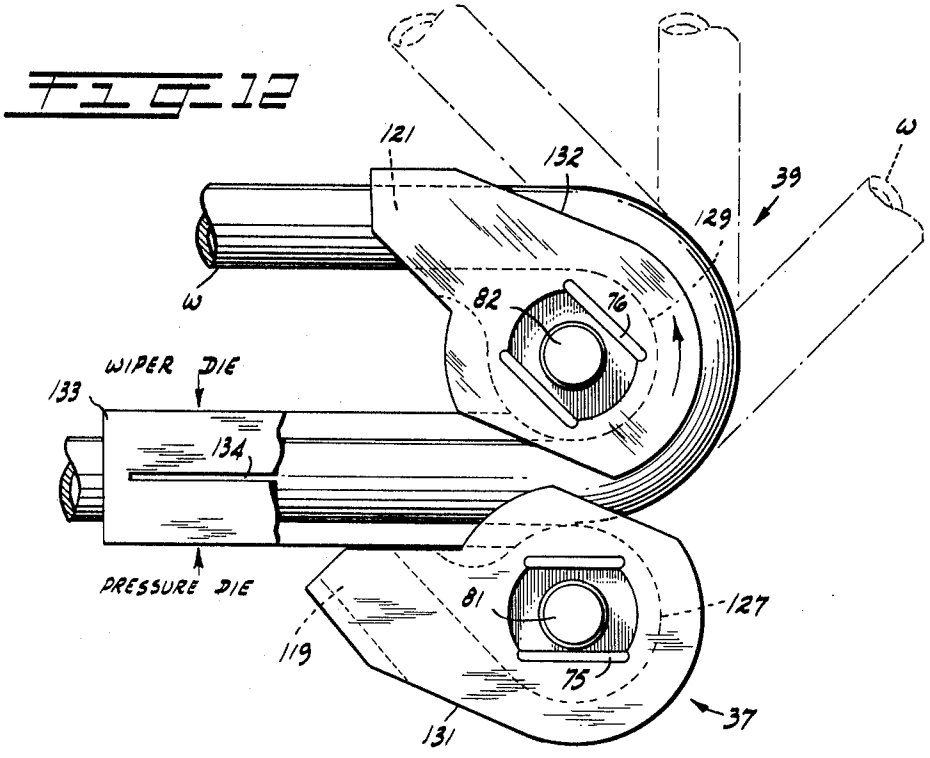

39
129
82
76
121
W
132
WIPER DIE
133
134
75
PRESSURE DIE
81
127
119
131
37

FIG. 12


121
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W
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129
82
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WIPER DIE
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134
PRESSURE DIE
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127
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75
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FIG. 13

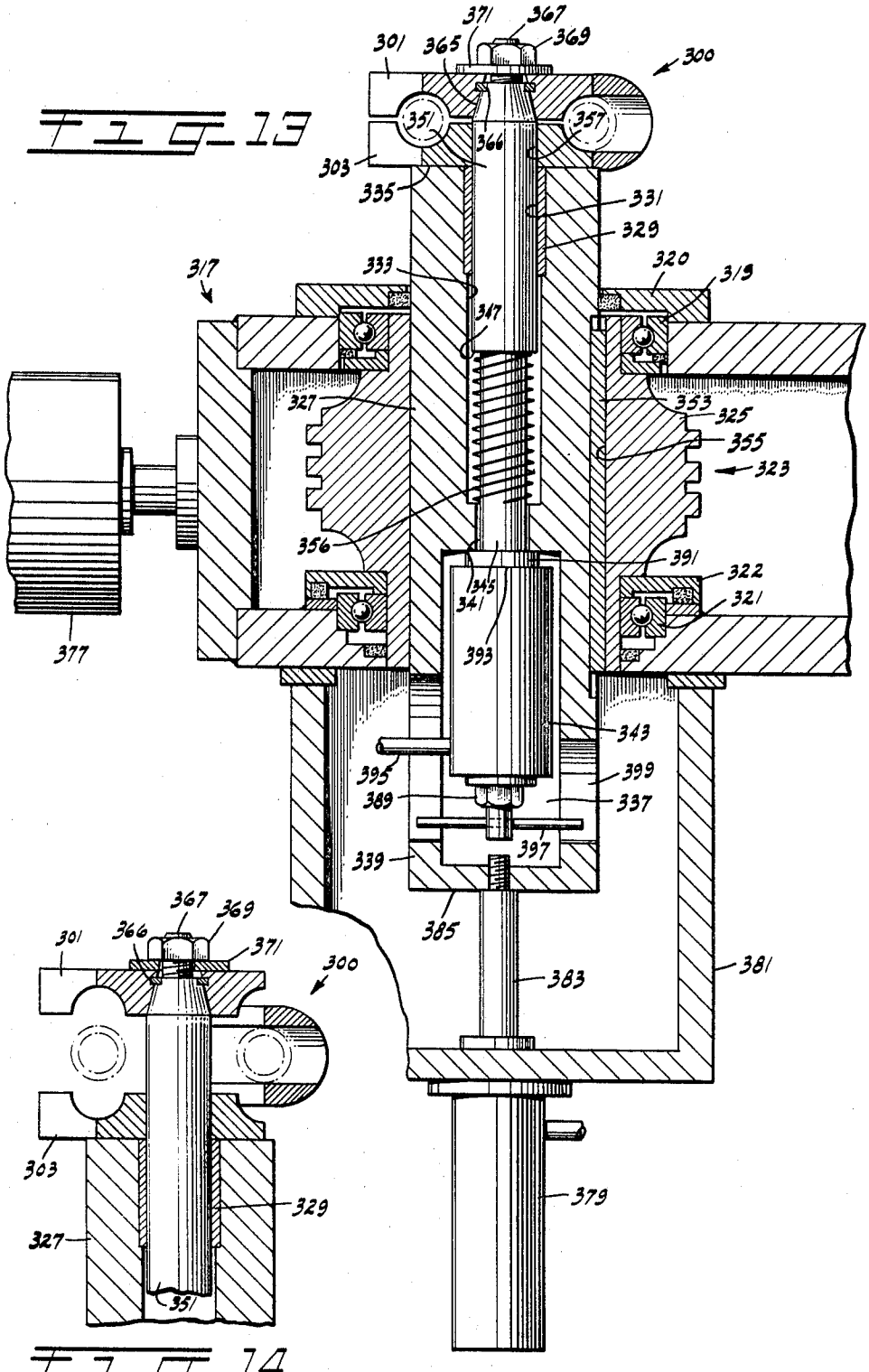

FIG. 14

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APPARATUS FOR BENDING

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Filed May 2, 1967, Ser. No. 635,545
Int. Cl. B21d 7/024, 7/04
U.S. Cl. 72—159 23 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus having at least one die assembly with an upper die block and a lower die block for clamping a tube and bending it in either direction in a common plane.

BACKGROUND

Although tube bending equipment has been available for a substantial period of time, no known serpentine bender has been available for heavy tubing such as used in a boiler shop. Although serpentine benders are known, such benders have all been limited by their design in their capacity to bend heavy tubing such as is found in a boiler shop. Since serpentine tube configurations are required on modern vapor generators, as well as other possible applications, the approach used to date has been to utilize a one-way bender having heavy-duty capacity for serpentine applications. This approach requires a separate apparatus located on the front of the one-way bender for repositioning the workpiece after each bend. Although operable, such apparatus is slow, initially expensive, and limited in flexibility of operation.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a pictorial representation of a complete bending machine utilizing the double bending assembly embodiment in accordance with this invention;

FIG. 2 is a front sectional view of the double bending assembly embodiment in accordance with this invention showing the bending heads in an open position;

FIG. 3 is a partial front sectional view similar to FIG. 2, but with the double bending assemblies in a closed position;

FIG. 4 is a partial side elevation of the bending machine showing that portion used for pushing-up the tube during the bending operation;

FIG. 5 is a cross-sectional view along line 5—5 of FIG. 4;

FIG. 6 is a partial sectional view of the upper bearings shown in FIG. 2 and FIG. 3 with the two adaptors in place;

FIG. 7 is a pictorial representation of the adaptor shown in FIGS. 2, 3 and 6;

FIG. 8 is a sectional view showing the drive gears and splined drive shafts shown in FIGS. 1, 2 and 3;

FIG. 9 is a top plan view showing the die assemblies with the left die assembly clamped to the tubular workpiece prior to beginning a bending operation;

FIG. 10 is a view similar to FIG. 9 with the upper tie bar and nuts removed showing the left die assembly with the tubular workpiece after a 180-degree bend with several intermediate bends shown in phantom;

FIG. 11 is a partial top plan view similar to FIG. 9 but with the upper tie bar and nuts removed showing the die assemblies with the right die assembly clamped to the tubular workpiece prior to beginning a bending operation;

FIG. 12 is a view similar to FIG. 11 showing the right die assembly with the tubular workpiece after a 180-degree bend with several intermediate bends shown in phantom;

FIG. 13 is a front sectional view of the single die assembly embodiment with the die blocks in the closed position;

FIG. 14 is a fragmentary view of the upper portion of the single die assembly shown in FIG. 13 but with the single die assembly in an open position;

FIG. 15 is a plan top plan view partially sectioned showing the single die assembly and the wiper die with the wiper die withdrawn and the workpiece formed into an offset bend;

FIG. 16 is a top plan view partially sectioned showing an alternate embodiment utilizing a single die assembly and the wiper die with the tubular workpiece after a 180-degree bend in the clockwise direction; and

FIG. 17 is a schematic view showing the path of travel of the single die assembly in relation to the workpiece required to change the direction of bend.

SUMMARY

An upper die block and a lower die block are separably arranged, within a bending apparatus, for receiving and clamping a workpiece. The workpiece is usually round and hollow but may have any other cross-sectional configuration and may be solid. Where the characteristics of the workpiece so requires, a wiper and pressure die assembly are included. Where serpentine bending is desired, the wiper and pressure die assembly is adapted to reverse the wiper die and pressure die functions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Double head embodiment

Referring now to FIG. 1, the entire machine utilized for the double twin head embodiment is supported by and partially encased within a housing **31**. A tubular workpiece W is fed into the machine from the rear end **33** to the forward end **35**. At the forward end **35** the left and right die assemblies **37**, **39** are located. The left die assembly **37** is driven by a left chain drive **41**. Located below the left chain drive **41** and to the right of it is a right chain drive **43**. The left chain drive **41** is actuated by a left power cylinder **45** while the right chain drive **43** is actuated by a right power cylinder (not shown). The left die assembly **37** and right die assembly **39** are opened and closed in unison by a left hydraulic cylinder **49** and a right hydraulic cylinder **51**.

Directly behind the die assemblies **37**, **39** along the path of the workpiece W is a push-up assembly **53** used to force the tubular workpiece W forward during the bending operation to assure proper wall thickness of the workpiece W after bending and to avoid collapse of the workpiece. At the rear end **33** of the machine is a feeding assembly **55** which is not an essential feature of this invention. However, it is useful for moving the workpiece W forward for each required bend and is required where a fully automatic operation is desired.

As best seen in FIGS. 2 and 3, the left die assembly **37** is mounted alongside the right die assembly **39**. The two die assemblies **37**, **39** are connected together by an upper tie bar **57** which limits the two die assemblies **37**, **39** so that they must open and close together. The left and right die assemblies **37**, **39** each have upper die blocks **59**, **61** and lower die blocks **63**, **65** which mate along a substantially horizontal plane. The left and right upper die blocks **59**, **61** are mounted rigidly at the upper ends of left and right upper clamping rods **67**, **69**. The upper clamping rod **67**, **69**, which are substantially vertically oriented, each have a cross-sectional shape which may be oval or broadly elliptical or generally rectangular. In FIG. 2 the left upper clamping rod **67** is shown

with the cross-section of the major diameter in view while the right upper clamping rod **69** is shown with the minor diameter cross-section in view. The upper portions **71, 72** of the two upper clamping rods **67, 69** which are in contact with the two upper die blocks **59, 61** converge upwardly to form a taper. Keyways **73, 74** are formed at the upper junction point of the two upper die blocks **59, 61** and the upper portions **71, 72** and keys **75, 76** are placed therein to prevent rotation between the upper clamping rods **67, 69** and the upper die blocks **59, 61.** Bearing rings **77, 78** are placed on top of each of the upper die blocks **59, 61.** Each of the bearing rings **77, 78** has an upper outwardly protruding lip **79,** which rests on the upper tie bar **57** to hold the upper tie bar **57** in place. Extending upwardly from the top of the upper portions **71, 72** of the upper clamping rods **67, 69** are left and right bolts **81, 82** with mating nuts **83, 84.** Each of the bearing rings **77, 78** has an inwardly protruding lip **85** to provide a seat for the nuts **83, 84** which are threaded down against the inwardly protruding lip **85.** The bearing rings **77, 78** are seated into the upper die blocks **59, 61.** The keyways **73, 74,** previously described, extend upwardly into the bearing rings **77, 78** as do the keys **75, 76** thereby assuring common rotation between the bearing rings **77, 78** and the upper die blocks **59, 61.** With lubrication between the upper tie bar **57** and the bearing rings **77, 78,** the bearing rings **77, 78** are free to rotate within the upper tie bar **57** so that the left and right die assemblies **37, 39** have the desired separate rotational motion.

Left and right power shafts **87, 89** are respectively mounted within left and right upper sleeve bearings **91, 93.** The sleeve bearings **91, 93** which are best seen in FIGS. 2, 3 and 6 extend around at least three-fourths of the circumference of the power shafts **87, 89** but not around the entire circumference as best seen in FIG. 6. As the sleeve bearings **91, 93** approach the space of near contact between the left power shaft **87** and the right power shaft **89,** they merge and join one another. So as to permit closing of the lower die blocks **63, 65,** the power shafts **87, 89** not only rotate but also slide longitudinally within the left and right upper sleeve bearings **91, 93** as can be seen by a comparison between FIGS. 2 and 3.

Located between the lower die blocks **63, 65** and the power shafts **87, 89** are left and right adaptor blocks **95, 97** which can best be seen in FIGS. 2, 3, 6 and 7. These adaptor blocks **95, 97** serve as a buffer between the lower die blocks **63, 65** and the power shafts **87, 89.** When different workpieces W having different cross-sectional sizes are fed to the machine for bending, the upper die blocks **59, 61** and lower die blocks **63, 65** must be changed. If the lower die blocks **63, 65** were connected directly to the power shafts **87, 89** frequent changes of the lower die blocks **63, 65** could result in a burring of the upper ends of the power shafts **87, 89.** By use of the adaptor blocks **95, 97** any such burring can be remedied by repair or replacement of only the adaptor blocks **95, 97.** As best seen in FIG. 7, the adaptor blocks **95, 97** each have an opening **99** located through their center region which opening **99** conforms to the cross-sectional shape of the upper clamping rods **67, 69.** The top surface **100** (FIG. 7) of each of the adaptor blocks **95, 97** has upper protrusions **101** situated generally radially on the surface **100.** Grooves **103,** similar in size and shape to the upper protrusions **101,** are located in the lower die blocks **63, 65** to receive the upper protrusions **101.** Similarly, the lower surface **104** of each of the adaptor blocks **95, 97** has lower protrusions **105** similar in size and configuration to the upper protrusions **101** which mate with grooves **107** in the power shafts **87, 89.** The protrusions **101, 105** and grooves **103, 107** of course, assure a strong connection for transferring torque from the power shafts **87, 89** to the lower die blocks **63, 65.** The lower die blocks **63, 65** are bolted to their respective adaptors **95, 97** by means of two bolts **109** threaded to bolt holes **109***a.* Similarly, bolt holes **110** are used with bolts (not shown) to secure the adaptors **95, 97** to the left and right power shafts **87, 89.**

The left and right upper clamping rods **67, 69** are mounted respectively in a central inner position within the left and right power shafts **87, 89.** Due to the cross-sectional shape of the upper clamping rods **67, 69,** and the similar shape of the openings **99** in the adaptor blocks **95, 97,** no interrotational relationship can exist between the upper clamping rods **67, 69** and the left and right power shafts **87, 89.** However, so as to move the upper die blocks **59, 61** for opening and closing the die assemblies **37, 39** intermovement along their longitudinal axes is required between the upper clamping rods **67, 69** and the openings **99** as well as the power shafts **87, 89.**

By comparing the cross-sectional view of the die assemblies **37, 39** shown in FIGS. 2 and 3 with the plan view of FIG. 10, the details of the die assemblies **37, 39** can best be understood. As previously pointed out, each of the die assemblies **37, 39** is formed from upper die blocks **59, 61** and lower die blocks **63, 65.** Each of the die assemblies **37, 39** includes (FIG. 10) hub portions **111, 113** with protruding arms **115, 117** extending from the hubs **111, 113.** Clamping channels **119, 121** are located within the protruding arms **115, 117** and are formed from grooves **123** in the upper die blocks **59, 61** and from grooves **125** in the lower die blocks **63, 65** which grooves **123, 125** mate with one another. Therefore the split between the upper die blocks **59, 61** and the lower die blocks **63, 65** parallels along the longitudinal axes of the clamping channels **119, 121.** In most cases, where round tubing is the workpiece W, the longitudinal axes of the clamping channels **119, 121** will be in the plane of the split between the upper die blocks **59, 61** and lower die blocks **63, 65.** However, where the workpiece W is of such a configuration that the portion of the workpiece W in the upper die blocks **59, 61** is not symmetrical with the portion of the workpiece W in the lower die blocks **63, 65,** the longitudinal axes of the clamping channels **119, 121** may not be in the plane of separation but will be in a plane parallel to the plane of separation between the upper die blocks **59, 61** and the lower die blocks **63, 65.**

About the hub portions **111, 113** of the die assemblies **37, 39** are circumferential grooves **127, 129** which are in a common plane with the clamping channels **119, 121.** The circumferential grooves **127, 129** lead off the inside or entrance openings **131, 132** of the clamping grooves **119, 121** to permit the workpiece W to bend against circumferential grooves **127, 129** on the hubs **111, 113** as the die assemblies **37, 39** rotate to bend the workpiece W.

Referring to FIGS. 9 through 12, a wiper and pressure die assembly **133** can be seen located along the line of feed of the workpiece W directly adjacent either the entrance **131** of the left clamping channel **119** or the entrance **132** of the right clamping channel **121** depending upon which of the channels **119, 121** is in the position of initial clamping as shown in FIGS. 9 and 11. The wiper and pressure die assembly **133** which is secured to the housing **31** by a holder (not shown), is formed from a hollow member through which the workpiece W passes. As is known in the bending art, a pressure die serves to force the workpiece from the outside of the bend against the bending wheel which in the invention would be the hubs **111, 113.** The wiper die supports the workpiece from the inside of the bend upstream of the point of bend to prevent buckling at that point. The wiper and pressure die assembly **133** serves both of these functions but reverses the two functions from side to side depending upon whether the left die assembly **37** or the right die assembly **39** is being used. During the translation or feeding of the workpiece W, it is essential that the feeding operation is as unrestricted as possible. Accordingly, the hollow member used herein as the wiper

and pressure die assembly **133** should be capable of easy sliding and still achieve the required pressure on the workpiece during the bending operation as previously mentioned. For these reasons an elongated slot **134** is placed in the top and bottom of the wiper and pressure die assembly **133**.

When bending with the left die assembly **37**, as shown in FIGS. 9 and 10, the right die assembly **39** is swung around counterclockwise so that the right arm **117** presses against the wiper and pressure die assembly **133** forming a pressure die function at the area of contact. When bending with the right die assembly **39**, as shown in FIGS. 11 and 12, the left die assembly **37** is swung around clockwise so that the left arm **115** presses against the pressure and wiper die assembly **133** creating a pressure die function at the point of contact.

Since the pressure of the arms **115**, **117** is not applied during the feeding of the workpiece W, the slot provides sufficient resilience to permit easy sliding of the workpiece W and still provide the pressure die function when pressure from the arms **115**, **117** is applied.

As can best be seen in FIG. 2, the upper portions **135**, **136** of the power shafts **87**, **89** have upper passages **137**, **139** each with a circular cross-section. As previously discussed, the adaptor blocks **95**, **97** serve as a buffer between the lower die blocks **63**, **65** and the power shafts **87**, **89**. In addition, without the use of the adaptor blocks **95**, **97** the upper passages **137**, **139** would have to have the same geometric cross-sectional configuration as the passages or openings **99** through the adaptor blocks **95**, **97**. Thus, by use of the adaptor blocks as a separate unit from the power shafts **87**, **89**, very difficult machining is eliminated. The diameter of the upper passages **137**, **139** is minutely larger than the major diameter of axis of the upper clamping rods **67**, **69** so as to permit sliding action between the clamping rods **67**, **69** and power shafts **87**, **89**.

The lower portions **141**, **142** of each of the power shafts **87**, **89** are journaled in left and right lower sleeve bearings **143**, **145** affixed to the bottom level of the housing **31**. Intermediate the lower portions **141**, **142** and upper portions **135**, **136** of each of the power shafts **87**, **89** are middle portions **147**, **148** which have splines **150** longitudinally located on their external surface. Mounted on the middle or splined portion **147** of the left power shaft **87** is a left drive gear **151** while a right drive gear **153** is mounted on the splined portion **148** of the right power shaft **89**. As can be seen in FIG. 2, the splined portions **147**, **148** cover a portion of the longitudinal length of the power shafts **87**, **89** for a length substantially longer than the thickness of the drive gears **151**, **153** so as to permit the power shafts **87**, **89** to move up and down without longitudinal movement of the drive gears **151**, **153**. Each of the drive gears **151**, **153** overlaps the opposite one of the power shafts **87**, **89** on which the other of the drive gears **151**, **153** is mounted. To permit rotation of the drive gears **151**, **153** without interference from the other of the power shafts **87**, **89** crescent-shaped cut outs **155**, **156** (FIG. 8) are formed in the drive gears **151**, **153**. The left drive gear **151** is mounted between thrust bearings **157** and the lower end of upper left bearing **91**. The right drive gear **153** is mounted between thrust bearings **158**. The left drive chain **41** (FIG. 1) is connected to the left drive gear **151** which is mounted on a higher level than the right drive gear **153**. The right drive gear **153** is actuated by the right drive chain **43**.

The left and right power shafts **87**, **89** have left and right lower passages **159**, **161** extending substantially concentrically from the lower ends **163** of the power shafts **87**, **89** to the upper passages **137**, **139**. In the left lower passage **159** a left lower clamping rod **165** is located. At the upper end of the left lower clamping rod **165** is a threaded end **167**. The upper threaded end **167** mates with a threaded opening **169** in the lower end of the left upper clamping rod **67** to form a threaded connection. The lower end of the left lower clamping rod **165** extends beyond the left power shaft **87** through the left hydraulic cylinder **49**. The upper end surface **173** of the left hydraulic cylinder **49** presses against the lower end surface **163** of the left power shaft **87**. By means of a nut **175** which mates with a lower threaded end **177** of the lower left clamping rod **165**, a lower tie bar **179** is pressed against the lower end surface **181** of the left hydraulic cylinder **49**. The piston **183** within the left cylinder **49** is fixedly mounted on the lower left clamping rod **165**. A left sleeve **185** is affixed to the piston **183** and mounted on the left lower clamping rod **165** below the piston **183**. An annular opening **187** in the left cylinder **49** about the left lower clamping rod **165** permits the left sleeve **185** to extend out of the left cylinder **49** and press against the lower tie bar **179** as best seen in FIG. 3.

In the right lower passage **161**, a right lower clamping rod **189** is located which is connected to the lower end **192** of the upper right clamping rod **69** by a threaded connection including a threaded end **193** and a threaded opening **195**. The right hydraulic cylinder **51** is virtually identical to the left hydraulic cylinder **49** and is mounted on the lower right clamping rod **189**. Within the right cylinder **51** is a piston **199** and right sleeve **200**. An annular opening **201** in the lower end surface **197** of the right cylinder **51** is provided to permit the right sleeve **200** to extend beyond the lower end surface **197** of the right cylinder **51**. A nut **203** mates with a lower threaded end **205** of the lower right clamping rod **189** to force the lower tie bar **179** against the lower end surface **197** of the right hydraulic cylinder **51**. The upper left clamping rod **67** and lower left clamping rod **165** in combination form a left clamping rod assembly **207**. Similarly, the upper right clamping rod **69** and lower right clamping rod **189** form a right clamping rod assembly **209**.

Directly above the two hydraulic cylinders **49**, **51** is a floating member **211**. Both power shafts **87**, **89** pass through the floating member **211** and are free to rotate in relationship to it. However, by means of snap rings **213** (FIG. 3), the floating member **211** is prevented from moving along the longitudinal axes of the two power shafts **87**, **89**. Mounted between the floating member **211** and the frame or housing **31** are spring means **215** to assist in sliding the power shafts **87**, **89** downwardly so as to lower the lower die blocks **63**, **65** to an open position.

To close the die assemblies **37**, **39**, hydraulic fluid under pressure is fed through left and right upper fluid ports **217**, **218** into the cylinders **49**, **51**. All fluid pressure is released at lower fluid ports **219**, **220**. As fluid pressure increases above the pistons **183**, **199**, the pistons **183**, **199** are forced downwardly. The pistons **183**, **199** thus force the sleeves **185**, **200** beneath them downwardly against the lower tie bar **179** thereby moving the lower tie bar **179** away from the lower end surfaces **181**, **197** of the two clamping cylinders **49**, **51**. A comparison of FIGS. 2 and 3 shows the change in position of the lower tie bar **179** and the clamping cylinders **49**, **51**. The downward movement of the lower tie bar **179** lowers the position of the left and right clamping assemblies **207**, **209**. In this manner, the two upper die blocks **59**, **61** are lowered. Lowering of the two upper die blocks **59**, **61** continues until the two upper die blocks **59**, **61** strike the workpiece W. Since the workpiece W prevents further downward movement of the upper die blocks **59**, **61**, the continued fluid pressure in the clamping cylinders **49**, **51** above the pistons **183**, **199**, forces the clamping cylinders **49**, **51** to move upwardly pushing the power shafts **87**, **89** upwardly along with the lower die blocks **63**, **65** against the resistance of the spring means **215**. This upward movement of the lower die blocks **63**, **65** continues until the lower die blocks **63**, **65** meet the upper die blocks **59**, **61**. Continuation of fluid pressure above the pistons

183, 199 assures positive clamping during the bending operation.

To open the die assemblies 37, 39, hydraulic fluid under pressure is fed through the lower fluid ports 219, 220 into the cylinders 49, 51. All fluid pressure is released at the upper fluid ports 217, 218. As the fluid pressure increases below the pistons 183, 199, the pistons 183, 199 are forced upwardly. The force of the spring means 215 along with the weight of the lower die blocks 63, 65 and power shafts 87, 89 causes the lower die blocks 63, 65 to drop. Continued fluid pressure against the lower surfaces 181, 197 of the two cylinders 49, 51 forces the clamping rod assemblies 207, 209 upwardly thereby moving the upper die blocks 59, 61 to their open position. Continued fluid pressure through the lower fluid ports 219, 220 retains the die assemblies 37, 39 in their open position.

The push-up assembly 53, previously referred to, can best be seen in FIGS. 4 and 5. The push-up assembly 53 is mounted on the housing 31 so as to be able to slide toward and away from the left and right die assemblies 37, 39. A push-up cylinder 221 which remains fixed to the housing 31 moves the push-up assembly 53 during the bending operation and positions the push-up assembly 53 in anticipation of a bending operation. Included in the push-up assembly 53 so as to slide with the assembly 53 is a locking cylinder 223 which serves to clamp and unclamp the workpiece W.

The workpiece W fits between an upper jaw 225 and a lower jaw 227. The upper jaw 225 is prevented from upward travel by a top member 229 which bridges across the top of two side members 231. The upper jaw 225 has an upper groove 233 and the lower jaw 227 has a lower groove 234 which mate to form a push-up channel 235 in which the workpiece W fits to be firmly clamped. The push-up channel 235 is located generally in a common plane with the left and right clamping channels 119, 121.

A front member 237 and a rear member 239 are secured to the two side members 231 but extend up only to the lower jaw 227 so as not to prevent access of the workpiece W to the push-up channel 235. The front and rear members 237, 239 are rigidly connected to two outside supports 241. Mounted on the outside supports 241 are rollers 243 which fit into slides 245 formed in the housing 31. Slidably fitted in the front member 237 is a slide pin 247 which is integrally formed with a slide block 249 in the rear member 239. The locking cylinder 223 actuates the slide block 249 and slide pin 247 and the piston rod 251 of the locking cylinder 223 is directly connected to the slide block 249 in line with but on the side opposite the slide pin 247.

A lower pivot link 253 extends downwardly and an upper pivot link 255 extends upwardly from the slide block 249. The pivot links 253, 255 are encased within the front and rear members 237, 239 and the two side members 231. The lower end of the lower pivot link 253 is pivotably mounted on the two side members 231 by a pin 259 and the upper end is pivotably mounted on the slide block 249 by a pin 260. The upper link 255 is pivotably mounted at its lower end on the slide block 249 by a pin 265 and at its upper end to the lower surface of a T-block 271 by a pin 273. The T-block 271 is slidably fitted within the front and rear members 237, 239 and the two side members 231. The upper surface of the T-block 271 presses against the lower jaw 227. As can be readily seen in FIG. 4, as the locking cylinder 223 forces the slide block 249 forward, the links 253, 255 move to an increasingly vertical position from an inclined position thereby forcing the T-block 271 upward and pulling the upper member 229 by means of the side members 231 downward thereby closing the lower jaw 227 against the upper jaw 225. Recessed portions 274 are formed in the side members 231 to provide space for the downstream portion of the workpiece W as shown in phantom in FIG. 5 when making a 180-degree bend.

OPERATION

The workpiece W to be bent in serpentine fashion is fed into the machine by the feeder assembly 55 (FIG. 1). When the workpiece W has been moved forward through the push-up assembly 53 and between the die assemblies 37, 39 a sufficient predetermined distance, the push-up mechanism 53 clamps the tube. For purposes of illustration, let it be assumed that a clockwise bend is desired, using a top view as a reference. This situation is illustrated in FIG. 9. In order to make a clockwise bend, the left die assembly 37 is utilized, requiring that the right die assembly 39 be rotated completely around out of position and on torque against the wiper and pressure die assembly 133. During the positioning operation, the die assemblies 37, 39 are left open as shown in FIG. 2. To rotate the right die assembly 39 completely around so that the outlet end of the right clamping channel 121 is located adjacent the right side of the wiper and pressure die assembly 133, the right power cylinder (not shown) is actuated thereby moving the right drive chain 43. Accordingly, the right drive gear 153 is rotated which rotates the right die assembly 39 through the right power shaft 89. The left die assembly 37 is rotated to place the left clamping channel 119 in line with the wiper and pressure die assembly 133. The left die assembly 37 is rotated by actuating the left power cylinder 45, thereby driving the left power shaft 87 by means of the left chain 41 and left drive gear 151 as previously explained with relation to the right die assembly 39.

With the die assemblies 37, 39 in position as shown in FIG. 9, the die assemblies 37, 39 are clamped together. Due to the position of the right die assembly 39, it does not clamp the workpiece W even though it closes with the left die assembly 37. However, as soon as the right die assembly 39 is closed, torque is applied to it to press against the wiper and pressure die assembly 133 as previously explained. The left die assembly 37, when positioned as shown in FIG. 9 with the left clamping channel 119 in line with the workpiece W, does clamp the workpiece W. Then by rotating the left die assembly 37 while retaining the left die assembly 37 in its closed or clamped position, a bend is achieved. To avoid tube collapse, the tube push-up mechanism 53 forces the workpiece W forward into the left die assembly 37 during the bending operation.

At the conclusion of the bend, the left and right die assemblies 37, 39 are opened and the push-up assembly 53 is also opened and retracts. The feeder mechanism 55 reclamps the tubular workpiece feeding it forward to the point of the next bend which, for purposes of illustration, will be considered to be counterclockwise as shown in FIGS. 11 and 12. In this situation, the left die assembly 37, while both die assemblies 37, 39 are open, is swung completely around clockwise to place the exit end of the left clamping channel 119 in close proximity to the wiper and pressure die assembly 133. The right die assembly 39 is rotated to place the right clamping channel 121 in line with the workpiece W. The die assemblies 37, 39 are closed together with only the right die assembly 39 clamping the workpiece W. Torque is applied to the left die assembly 37 to press the arm against the wiper and pressure die assembly 133. The right die assembly 39 is then rotated to accomplish the desired degree of bend while the push-up assembly 53 forces the workpiece W forward. The die assemblies 37, 39 are then reopened and positioned for the next bend desired.

By making alternating left and right U-bends a tube bank such as used in a heat exchanger can be rapidly produced. By making alternating bends of approximately 30 degrees, with a comparatively short length of the workpiece, an offset results. By means of a control system, not described, desired coordination between such factors as the desired push-up pressure and degree of bend can be achieved. Also an entire series of various predeter-

mined bends as well as the distance between them can be programmed.

SINGLE DIE ASSEMBLY EMBODIMENT

In the single die assembly embodiment shown in FIGS. 13 through 17, a single die assembly **300** with an upper die block **301** and a lower die block **303** are also utilized. However, as best seen in FIGS. 14 and 16, two straight through channels **304** are used in the single die assembly embodiment. The two straight through channels **304** include a left channel **305** and a right channel **306**. The left channel **305** has an inlet end **307** and an outlet end **308**. Similarly, the right channel **306** has an inlet end **309** and an outlet end **310**. The die assembly **300** includes a hub **311** with an arm **313** extending from a portion of the circumference of the hub **311**. The left channel **305** and the right channel **306** are located in the arm **313** at substantially right angles to one another. However, other geometric relationships are possible between the channels **305, 306**. Both channels **304** extend their entire longitudinal length in both the upper die block **301** and the lower die block **303**. As discussed with reference to the double head embodiment, the longitudinal axes of the channels **304** is parallel to the plane of contact between the upper die block **301** and the lower die block **303**. When the workpiece W is round, the cross-section of channels **304** is located substantially equally in both the upper die block **301** and the lower die block **303**. When the workpiece W is not symmetrical, there may not be an equal distribution between the two die blocks **301, 303**.

Located on the circumference of the hub **311** is a groove **316** which extends from the inlet end **307** of the left channel **305** to the inlet end **309** of the right channel **306**. Like the two channels **304**, the groove **316** is distributed between the upper die block **301** and the lower die block **303**.

The bending apparatus is supported by a frame **317**. Attached to the frame **317**, directly above one another is an upper tapered roller bearing **319** which is held in place by an upper hub **320** and a lower tapered roller bearing **321** which is held in place by a lower hub **322**. Rotatably mounted within the upper and lower bearings **319, 321** is a vertically-oriented drive assembly **323**. The drive assembly **323** includes a drive gear **325** which is actuated by a drive chain (not shown) such as the drive chains **41, 43** described in relation to the prior embodiment. Concentrically mounted within the drive gear **325** is a power shaft **327** which extends substantially vertically above the drive gear **325** and the frame **317** and on which is mounted the lower die block **303**. An upper passage **333** extends from the upper end **335** down a substantial portion of the length of the power shaft **327** and is substantially concentrically located along the longitudinal axis. A lower passage **337** extends concentrically along the longitudinal axis from the lower end **339** and is larger in cross-section than the upper passage **333**. A middle passage **341** along the longitudinal axis connects the upper passage **333** and the lower passage **337** and is smaller in cross-section than the upper passage **333**.

A hydraulic cylinder **343** is located at least partially in the lower passage **337**. A lower clamping rod **345** extends upwardly through the middle passage **341** into the upper passage **333**. The upper end **347** of the lower clamping rod **345** is connected by a rigid joint to an upper clamping rod **351** which upper clamping rod **351** has either an oval or generally elliptical or rectangular cross-section. The power shaft **327** is keyed to the clamping rod **351** by a key **329** and a keyway **331** and is keyed to the drive gear **325** by a key **353** and keyway **355**. Both keyways **331, 355** extend along the longitudinal length of the power shaft **327** for a distance longer than the keys **329, 353** to permit the power shaft **327** to move longitudinally in relationship to the drive gear **325** and for the upper clamping rod **351** and power shaft **327** to move longitudinally in relation to one another. A coil spring **356** coiled about the lower clamping rod **345** extends from the lower end of the upper passage **333** to the lower end of the upper clamping rod **351**. The spring **356** serves to assist in the opening of the die assembly **300** to be explained later.

Mounted on the uper end of the power shaft **327** is the lower die block **303**. An opening **357** at the centerpoint of the lower die block **303** is shaped consistent with the cross-section of the clamping rod **351** but is slightly larger to permit the upper clamping rod **351** to slide through it. The shape of the opening **357** and the upper clamping rod **351** assures common rotation between the lower die block **303** and the upper clamping rod **351**.

The upper end of the clamping rod **351** is secured rigidly to the centerpoint of the upper die block **301**. The portion of the upper clamping rod **351** from the lower surface to the upper surface of the upper die block **301** is the frustum **365** of a right circular cone. By means of a key and keyway **366**, common rotation of the upper die block **301** with the clamping rod **351** is assured and the frustum **365** prevents any longitudinal movement between the upper die block **301** and the clamping rod **351**.

A threaded bolt **367** extends from the upper surface of the uper die block **301** to slightly above it to permit a nut **369** and a washer **371** to clamp the upper die block **301** onto the frustum portion **365**.

Referring to FIG. 16, a wiper and pressure die assembly **373** is shown in contact with the die assembly **300**. The wiper and pressure die assembly **373** is located along the line of feed of the workpiece W directly adjacent the die assembly **300**. The forward end of the wiper die **373** which is in contact with the die assembly **300** is shaped to be in contact with the groove **316**. The wiper and pressure die assembly **373** assures rigidity along the workpiece W where buckling normally would occur as a result of the bending operation. Positioning of the wiper and pressure die assembly **373** will be described subsequently.

In FIG. 13, a horizontal locating cylinder **377** and a vertical locating cylinder **379** can be seen. The horizontal locating cylinder **377** moves the frame **317** in a horizontal plane while the vertical locating cylinder **379** moves the power shaft **337** in a vertical plane.

The mechanism for supporting the entire structure fastened to the frame **317** when moved by the horizontal locating cylinder **377** is not shown but may utilize any suitable slide-roller concept. The vertical locating cylinder **379** is hung from the frame **317** by supports **381**. The piston rod **383** of the vertical locating cylinder **379** extends vertically upward through the supports **381**. The upper end of the piston rod **383** is secured to a circular hub **385** which has dimensions suitable to mate with the lower end of the power shaft **337**. In this way, the entire power shaft **337** is moved vertically up and down within the drive wheel **325** in accordance with the prior discussion.

The spring means **356** extends between the protrusion **341** and the lower end of the upper clamping rod and forces the upper clamping rod upward when there is no fluid pressure. The lower clamping rod **345** extends through the hydraulic cylinder **343** and is rigidly secured to the lower end of the hydraulic cylinder **343** by a nut **389**. A piston (not shown) within the cylinder **343** is slidably mounted on the lower clamping rod **345**. An annular sleeve **391**, also slidably mounted on the lower clamping rod **345**, extends through an annular opening **393** at the upper end of the hydraulic cylinder. As fluid pressure is applied to the hydraulic cylinder **343** through a fluid inlet **395**, the annular sleeve **391**, pushes upward against the protrusion **341** thereby forcing the power shaft **327** upward along with the lower die block **303**. The fluid pressure also forces the lower end of the hydraulic cylinder **343** downward which pulls the lower clamping rod **345** and the upper clamping rod **351** downward. Since the upper die block **301** is attached to the upper clamping rod **351**, the uper die block **301** is firmly pressed against

the upward force of the lower die block **303**. A key shaft **397** is attached to the lower end of the lower clamping rod **345** below the nut **389** to prevent rotation of the hydraulic cylinder **343**. Slots **399** permit longitudinal movement of the hydraulic cylinder **343**. When the fluid pressure is released from the fluid inlet **395**, the spring means **356** forces the upper die block **301** and the lower die block **303** apart.

When the wiper and pressure die assembly **300** changes sides in relation to the workpiece W, the wiper and pressure die assembly **373** is rotated 180 degrees so that it will properly contact the groove **316**. A rotating mechanism (not shown) is used to achieve the desired movement of the wiper die **373** and to secure the assembly **373** to the frame **317**.

In FIG. 17 the required movement of the single die assembly **300** is shown when changing from the left channel **305** to the right channel **306** or vice versa. When utilizing the left channel **305** to make a clockwise bend (equivalent to the left die assembly **37** of the two head embodiment) the wiper die **373** is located as shown in FIG. 14. When making a counterclockwise bend (equivalent to the righet die assembly **39** of the two head embodiment) the wiper die **373** must be rotated 180 degrees and pulled back to accommodate the opposite side of the die assembly **300**. To achieve the transfer, the single head die assembly **300** is pulled horizontally off the workpiece W, dropped vertically, pushed horizontally to beyond the opposite side of the workpiece W, moved vertically upward and pulled horizontally over to the workpiece W. Of course, all vertical movements are accomplished by the vertical locating cylinder **379** and all horizontal movements are accomplished by the horizontal locating cylinder **377**.

OPERATION

As with the twin-head embodiment, the workpiece W would be fed through means such as the feeder mechanism **55** and the push-up assembly **53**. Assuming a bend such as would be made with the left die assembly **37** of the twin-head embodiment, the left channel **305** would be used as shown in FIG. 16. The upper and lower die blocks **301**, **303** are opened and the workpiece W placed in the channel **305**. The wiper and pressure die assembly is placed on the right side of the single head die assembly, as is also shown in FIG. 16. The channel **305** is aligned with the wiper and pressure die assembly **373**. The upper die block **301** and the lower die block **303** are clamped together with the workpiece W within the channel. The upper die block and lower die block are then rotated as previously explained to obtain the desired bend.

The single-head die assembly is opened at the conclusion of the desired bend. Assuming a bend in the opposite direction is then desired, the wiper and pressure die assembly **373** is rotated one-half turn and the single-head die assembly is moved to the opposite side of the wiper and pressure die assembly **373** as shown in FIG. 17. The upper and lower die blocks **301**, **303** may be closed once the workpiece W has been released. The right channel **306** is aligned with the wiper die and the upper and lower die blocks **301**, **303** held open while the workpiece is located for the desired bend. The die blocks **301**, **303** are then clamped together on the workpiece W and the desired bend is accomplished.

As is visually shown in FIG. 16, an offset bend in the workpiece W can be accomplished by withdrawing the wiper die **373** a predetermined amount and using the horizontal locating cylinder **377** to move the die assembly **300**, thereby effecting an offset bend on the workpiece W between the die assembly **300** and the wiper die **373**.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred forms has been made only by way of example and that numerous changes in the details of construction and the combination and arrangements of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. An apparatus for bending a workpiece comprising:
- a die assembly means separable into an upper die block and a lower die block and including a bending hub, said die assembly further including a channel through it, said channel being located along its longitudinal axis in both the upper die block and the lower die block to clamp a workpiece;
- means including two shaft means slidably fitted together for separating the upper die block and the lower die block from one another to receive the workpiece within the channel and for forcing together the upper die block and the lower die block to clamp the workpiece within the channel; and
- means for rotating the die assembly means with the workpiece clamped within the channel to bend the workpiece about the bending hub.

2. An apparatus for bending a workpiece according to claim **1** further including:
- a wiper die means to prevent buckling of the workpiece during bending of the workpiece.

3. An apparatus for bending a workpiece according to claim **2** further including:
- a pressure die means to force the workpiece against the bending hub during bending of the workpiece.

4. An apparatus for bending a workpiece according to claim **3** further including:
- a push-up means for forcing the workpiece through the wiper die means and pressure die means into the die assembly to prevent cross-sectional deformation of the workpiece.

5. An apparatus for bending a workpiece comprising:
- a die assembly including a bending hub, said die assembly being separable along a substantially horizontal plane into an upper die block and a lower die block with a circular channel through the die assembly, said channel being located along its longitudinal axis substantially equally in both the upper die block and the lower die block to form a clamp for a workpiece;
- means including two shaft means slidably fitted together for moving the upper die block upwardly and the lower die block downwardly to separate the upper die block and the lower die block and for moving the upper die block downwardly and the lower die block upwardly to close the upper die block and lower die block; and
- means for rotating the die assembly with the workpiece clamped within the channel to bend the workpiece about the bending hub.

6. An apparatus for bending a workpiece according to claim **5** further including:
- a wiper and pressure die assembly means located adjacent said circular channel about the workpiece to force the workpiece against the bending hub and to prevent buckling of the workpiece during the bending of the workpiece.

7. An apparatus for bending a workpiece according to claim **6** further including:
- a push-up means for forcing the workpiece through the wiper and pressure die assembly means into the die assembly during the rotation of the die assembly.

8. An apparatus for bending a workpiece comprising:
- a die assembly including a hub with an arm extending outwardly from a portion of the circumference of the hub, said arm having a channel extending in substantially a straight line through it, said channel having an inside opening and an outside opening, said hub having a groove about its circumference extending from the inside end of the channel to adjacent the outside end, said die assembly being split into an upper die block and a lower die block along a plane in which are located the centerline of said channel and groove;

a wiper and pressure die assembly means located adjacent said die assembly about the workpiece to force the workpiece against the die assembly and to prevent buckling during rotation of the die assembly;

means for opening the upper die block and the lower die block to receive a workpiece within the channel and to close the upper die block and the lower die block to clamp the workpiece within the channel; and

means for rotating the die assembly with the workpiece clamped within the channel to wrap the workpiece around the groove for a predetermined angle.

9. An apparatus according to claim **8** further including:

a push-up means for forcing the workpiece through the wiper and pressure die assembly means into the die assembly during bending to prevent cross-sectional deformation of the workpiece.

10. An apparatus for bending comprising:

a die assembly including a bending hub split into an upper die block and a lower die block with a channel through the die assembly, said channel being located along its entire longitudinal length substantially equally in both the upper die block and the lower die block to form a clamp for a workpiece;

a frame means;

a clamping rod assembly means slidably extending through the centerpoint of the lower die block and being secured to the upper die block;

a power shaft means rotatably mounted in said housing means and secured to the lower die block, said clamping rod assembly means being slidably fitted within said power shaft means and along the centerline of said power shaft means and being adapted to rotate with said power shaft means;

means for moving said clamping rod assembly means and said power shaft means in opposite longitudinal directions to open the die assembly to receive the workpiece and to close the die assembly to clamp the workpiece within the channel of the die assembly; and

means for rotating the power shaft means whereby the die assembly is rotated with the workpiece clamped therein to bend the workpiece.

11. An apparatus for bending a workpiece according to claim **10** further including:

a wiper and pressure die assembly means located adjacent said die assembly about the workpiece to force the workpiece against the die assembly and to prevent buckling during rotation of the die assembly.

12. An apparatus for bending a workpiece according to claim **10** further including:

a wiper and pressure die assembly means located adjacent said die asssembly about the workpiece to force the workpiece against the bending hub to prevent buckling during rotation of the die assembly; and

a push-up means for forcing the workpiece through the wiper die means into the die assembly during bending of the workpiece to prevent cross-sectional deformation of the workpiece.

13. An apparatus for bending a workpiece comprising:

a die assembly including a hub with an arm extending outwardly from a portion of the circumference of the hub, said arm having a channel extending in substantially a straight line through it, said channel having an inside opening and an outside opening, said hub having a rounded groove about its circumference extending from the inside end of the channel to adjacent the outside end, said die assembly being split into an upper die block and a lower die block along a plane in which are located the centerlines of said channel and groove;

a frame means;

a clamping rod assembly means slidably extending through the centerpoint of the hub of the lower die block and being secured to the centerpoint of the hub of the upper die block;

a power shaft means rotatably mounted in said housing means and secured to said hub of said lower die block, said clamping rod assembly means being slidably fitted along the centerline of said power shaft means and being adapted to rotate with said power shaft means;

means for moving said clamping rod assembly means and said power shaft means in opposite longitudinal directions to open the die assembly to receive a workpiece and to close the die assembly to clamp the workpiece within the channel of the die assembly; and

a wiper and pressure die assembly means located adjacent said die assembly about the workpiece to force the workpiece against the die assembly and to prevent buckling during rotation of the die assembly; and

means for rotating the power shaft means in a direction to rotate the die assembly with the outside opening of the channel leading the inside opening whereby the workpiece is wrapped around the groove to a predetermined angle.

14. An apparatus for bending a workpiece according to claim **13** further including:

a push-up means for forcing the workpiece through the wiper and pressure die assembly means into the die assembly during bending.

15. An apparatus for bending a workpiece comprising:

a first die assembly means separable into a first upper die block and first lower die block and including a first bending hub, said first die assembly further including a first channel through it, said first channel being located along its longitudinal axis in both the first upper die block and the first lower die block to clamp a workpiece;

a second die assembly means separable into a second upper die block and a second lower die block and including a second bending hub, said second die assembly further including a second channel through it, said second channel being located along its longitudinal axis in both the second upper die block and the second lower die block to clamp a workpiece;

means for separating the first upper die block and the first lower die block from one another to receive the workpiece within the first channel and for forcing together the first upper die block and the first lower die block to clamp the workpiece within the first channel;

means for separating the second upper die block and the second lower die block from one another to receive the workpiece within the second channel and for forcing together the second upper die block and the second lower die block to clamp the workpiece within the second channel;

means for rotating the first die assembly means to align the first channel with the workpiece and to bend the workpiece about the first bending hub to remove the first channel from the location of the workpiece; and

means for rotating the second die assembly means to align the second channel with the workpiece and to bend the workpiece about the second bending hub and to remove the second channel from the location of the workpiece.

16. An apparatus for bending a workpiece according to claim **15** further including:

a wiper and pressure die assembly means located adjacent the first die assembly means and the second die assembly means about the workpiece to force the workpiece against the first hub and the second hub and to prevent buckling of the workpiece during bending of the workpiece.

17. An apparatus for bending a workpiece according to claim **10** further including:

a push-up means for forcing the workpiece through the wiper and pressure die assembly means into the first die assembly means and into the second die assembly means.

18. An apparatus for bending a workpiece comprising:

a left die assembly including a left hub with a left arm extending outwardly from a portion of the circumference of the left hub, said left arm having a left channel extending in substantially a straight line through it, said left channel having an inside opening and an outside opening, said left hub having a left groove about its circumference extending from the inside end of the left channel to adjacent the outside end, said left die assembly being split into a left upper die block and a left lower die block along a plane in which are located the centerlines of the left channel and left groove;

a right die assembly including a right hub with a right arm extending outwardly from a portion of the circumference of the right hub, said right arm having a right channel extending in substantially a straight line through it, said right channel having an inside opening and an outside opening, said right hub having a right groove about its circumference extending from the inside end of the channel to adjacent the outside end, said right die assembly being split into a right upper die block and right lower die block along a plane in which are located the centerlines of said right channel and said right groove, said left die assembly and said right die assembly being located adjacent one another at substantially the same vertical position;

means for separating the left upper die block and the left lower die block and to close the left upper die block and the left lower die block whereby the workpiece is clamped within the left channel;

means for separating the right upper die block and the right lower die block and to close the right upper die block and the right lower die block whereby the workpiece is clamped within the right channel;

a wiper and pressure die assembly means located adjacent said left die assembly and said right die assembly, said wiper and pressure die assembly means having a passage through which the workpiece is fed, the distance from the centerpoint of the left hub to the longitudinal axis of the left channel being substantially equal to the distance from the centerpoint of the left hub to the longitudinal axis of the passage through the wiper and pressure die assembly means and the distance from the centerpoint of the right hub to the longitudinal axis of the right channel being substantially equal to the distance from the centerpoint of the right hub to the longitudinal axis of the passage through the wiper and pressure die assembly means;

means for rotating the left die assembly to position the left channel in line with the channel of the wiper and pressure die assembly means and to remove the left arm from the channel of the wiper and pressure die assembly means and for rotating the left die assembly with the workpiece clamped in the left channel to bend the workpiece in the direction of rotation from the inside opening to the outside opening of the left channel by pulling the workpiece against the left groove; and

means for rotating the right die assembly to position the right channel in line with the channel of the wiper and pressure die assembly means and to remove the right arm from the channel of the wiper and pressure die assembly means and for rotating the right die assembly with the workpiece clamped in the right channel to bend the workpiece in the direction of rotation from the inside opening to the outside opening of the right channel by pulling the workpiece against the right groove.

19. An apparatus for bending a workpiece comprising:

a left die assembly including a left hub with a left arm extending outwardly from a portion of the circumference of the left hub, said left arm having a left round channel extending in substantially a straight line through it, said left hub having a left rounded groove about its circumference extending from the inside end of the left channel to adjacent the outside end, said left die assembly being split into a left upper die block and a left lower die block along a plane in which are located the centerlines of the left channel and left groove;

a right die assembly including a right hub with a right arm extending outwardly from a portion of the circumference of the right hub, said right arm having a right round channel extending in substantially a straight line through it, said right hub having a right rounded groove about its circumference extending from the inside end of the channel to adjacent the outside end, said right die assembly being split into a right upper die block and a right lower die block along a plane in which are located the centerlines of said right channel and said right groove, said left die assembly being located adjacent one another in a common plane;

a frame means;

a push-up means slidably mounted on said frame means for forcing the workpiece into the bend during the bending operation, said push-up means including an upper jaw member and a lower jaw member, said upper jaw member and said lower jaw member including a clamping channel located along its longitudinal axis substantially equally in said upper jaw member and said lower jaw member, said clamping channel lying substantially in a common plane with said left round channel and said right round channel, said push-up means further including a push-up cylinder for sliding said clamping means toward and away from said left die assembly and said right die assembly and a clamping cylinder for clamping said upper jaw member and lower jaw member together;

an upper tie bar rotatably connected to the top of the left die assembly and to the top of the right die assembly;

a left upper clamping rod slidably extending through the centerpoint of the left hub of the left lower die block and being rigidly secured to the centerpoint of the left hub of the left upper die block, said left upper clamping rod having a cross-section adapted to permit said left lower die block to rotate with said left upper clamping rod and slide along the longitudinal axis of the left upper clamping rod;

a left adaptor rigidly secured to the lower surface of said left lower die block, said left upper clamping rod slidably extending through the left adaptor;

a left power shaft having a circular cross-section engaged with the lower surface of said left adaptor, said left power shaft having an upper portion, a middle portion, and a lower portion, said upper portion having an upper circular passage therein slightly larger than the cross-section of the left upper clamping rod, said middle portion having an external diameter smaller than the external diameter of said upper portion and said middle portion having splines longitudinally located thereon, said lower portion having an external diameter smaller than said middle portion, both said middle portion and said lower portion having a lower passageway along the longitudinal axis from the upper passageway to the lower end of the lower portion, said left upper clamping rod extending into said left upper passage;

a left upper bearing means partially encompassing the external surface of the upper portion of the left power shaft, said left upper bearing means being secured to said frame means;

a left lower bearing means secured to said frame means, said lower portion of said left power shaft being journaled therein;

a left lower clamping rod secured at its upper end to the lower end of said left upper clamping rod and extending beyond the lower end of said lower portion of said left power shaft;

a right upper clamping rod slidably extending through the centerpoint of the right hub of the right lower die block and being rigidly secured to the centerpoint of the right hub of the right upper die block, said right upper clamping rod having a cross-section adapted to permit said right lower die block to rotate with said right upper clamping rod and slide along the longitudinal axis of the right upper clamping rod;

a right adaptor rigidly secured to the lower surface of said right lower die block, said right upper clamping rod slidably extending through the right adaptor;

a right power shaft having a circular cross-section engaged with the lower surface of said right adaptor, said right power shaft having an upper portion, a middle portion, and a lower portion, said upper portion having an upper circular passage therein slightly larger than the cross-section of the right upper clamping rod, said middle portion having an external diameter smaller than the external diameter of said upper portion, and being splined, said lower portion having an external diameter smaller than said middle portion, both said middle portion and said lower portion having a lower passageway along the longitudinal axis from the upper passageway to the lower end of the lower portion, said right upper clamping rod extending into said right upper passage;

a right upper bearing means partially encompassing the external surface of the upper portion of the right power shaft, said right upper bearing means being secured to said frame means;

a right lower bearing means secured to said frame means, said lower portion of said left power shaft being journaled therein;

a right lower clamping rod secured at its lower end to the lower end of said right upper clamping rod and extending beyond the lower end of said lower portion of said right power shaft;

a lower tie bar secured to the lower end of said left lower clamping rod and to the lower end of said right lower clamping rod;

a left hydraulic clamping cylinder located about the lower end of said left lower clamping rod, the lower end of said left hydraulic clamping cylinder resting against said lower tie bar and the upper end of said left hydraulic clamping cylinder resting against the lower end of said left power shaft, a left piston being mounted on the lower end of said left lower clamping rod within said left hydraulic cylinder;

a left sleeve mounted on the lower end of said left lower clamping rod, the upper end of said left sleeve being in contact with said left piston and the lower end in contact with said lower tie bar, the lower end of said left hydraulic clamping cylinder having an annular opening about said left lower clamping rod to permit said left sleeve to extend through the left hydraulic clamping cylinder;

a right hydraulic clamping cylinder located about the lower end of said right lower clamping rod, the lower end of said right hydraulic clamping cylinder resting against said lower tie bar and the upper end of said right hydraulic clamping cylinder resting against the lower end of said right power shaft, a right piston being mounted on the lower end of said right lower clamping rod within said right hydraulic cylinder;

a right sleeve mounted on the lower end of said right lower clamping rod, the upper end of said left sleeve being in contact with said right piston and the lower end in contact with said lower tie bar, the lower end of said right hydraulic clamping cylinder having an annular opening about said right lower clamping rod to permit said right sleeve to extend through the right hydraulic clamping cylinder;

a floating bar located across the lower portions of said left power shaft and said right power shaft, said left and right power shafts being rotatably journaled through said floating bar;

snap ring means about said left and right power shafts adjacent said floating bar to prevent longitudinal movement by said floating bar along the longitudinal axes of said left and right power shafts;

spring means extending between said floating bar and said frame means to force said left and right power shafts downwardly;

upper inlet means for supplying hydraulic fluid under pressure into said left and right hydraulic cylinders above said left and right pistons thereby forcing said left and right lower and upper clamping rods downward until said left and right upper die blocks contact the workpiece and then forcing said left and right power shafts upwardly against said spring means until said left and right lower die blocks press against said left and right upper die blocks;

lower inlet means for supplying hydraulic fluid under pressure into said left and right hydraulic cylinders below said left and right pistons thereby permitting said spring means to force said left and right power shafts downwardly thereby lowering said left and right lower die blocks and then forcing said left and right lower and upper clamping rods upwardly thereby raising said left and right upper die blocks;

a wiper and pressure die assembly means located adjacent said left die assembly and said right die assembly, said wiper and pressure die assembly means having a passage through which the workpiece is fed, the distance from the centerpoint of the left hub to the longitudinal axis of the left channel being substantially equal to the distance from the centerpoint of the left hub to the longitudinal axis of the passage through the wiper die means and the distance from the centerpoint of the right hub to the longitudinal axis of the right channel being substantially equal to the distance from the centerpoint of the right hub to the longitudinal axis of the passage through the wiper and pressure die assembly means;

a left drive gear mounted on the middle portion of said left power shaft and adapted to engage the splines on the middle portion of the left power shaft to transmit torque to it and to slide longitudinally along the splines during longitudinal movement of the left power shaft, said left drive gear having a crescent-shaped cut out through which said right power shaft extends;

a left drive gear bearing means mounted on the frame means to support the left drive gear in a horizontal plane;

a right drive gear mounted on the middle portion of said right power shaft and adapted to engage the splines on the middle portion of the right power shaft to transmit torque to it and to slide longitudinally along the splines during longitudinal movement of the right power shaft, said right drive gear having a crescent-shaped cut out through which said left power shaft extends;

a right drive gear bearing means mounted on the frame means to support the right drive gear in a horizontal plane;

a left drive means including a left chain engaged with said left drive gear to rotate the left die assembly thereby positioning the left channel in line with the channel of the wiper die and removing the left arm from the workpiece and to rotate the left die assembly with the workpiece clamped in the left chan-

nel to bend the workpiece in the direction of rotation from the inside opening to the outside opening of the left channel by pulling the workpiece against the left groove; and

a right drive means including a right chain engaged with said right drive gear to rotate the right die assembly thereby positioning the right channel in line with the channel of the wiper die and removing the right arm from the workpiece and to rotate the right die assembly with the workpiece clamped in the right channel to bend the workpiece in the direction of rotation from the inside opening to the outside opening of the right channel by pulling the workpiece against the right groove.

20. An apparatus for bending a workpiece comprising:

a die assembly split into an upper die block and a lower die block with a first channel and a second channel each located along their longitudinal lengths in both the upper die block and the lower die block to form separate clamps for a workpiece, said die assembly including a bending hub;

means for separating the upper die block and the lower die block to receive a workpiece and to close the upper die block and the lower die block to clamp the workpiece; and

means for rotating the die assembly with a workpiece clamped therein to bend the workpiece about the bending hub.

21. An apparatus for bending a workpiece according to claim **20** wherein said first channel and said second channel are located substantially at right angles to one another.

22. An apparatus for bending a workpiece comprising:

a die assembly including a hub with an arm extending outwardly from a portion of the circumference of the hub, said arm having a first channel and a second channel both extending in substantially a straight line through it, said first channel and said second channel each having an inside opening and an outside opening and being at substantially right angles to one another, said die assembly being split into an upper die block and a lower die block along a plane in which are located the centerlines of said first channel and said second channel and said groove;

a wiper and pressure die assembly means located adjacent said die assembly about the workpiece to force the workpiece against the hub and to prevent buckling of the workpiece during bending of the workpiece, said wiper die having a channel therein through which the workpiece is fed;

means for opening the upper die block and the lower die block to receive a workpiece within the first channel and within the second channel and to close the upper die block and the lower die block to clamp the workpiece within the first channel and within the second channel; and

means for rotating the die assembly to wrap the workpiece around the hub for a predetermined angle.

23. An apparatus for bending a workpiece according to claim **22** further including:

means for positioning the die assembly on opposite sides of the workpiece to align both the first channel and the second channel with the channel in the wiper die; and

means for rotating the wiper and pressure die assembly means about the longitudinal axis of the channel therein to adapt the wiper and pressure die assembly means to both the first channel and the second channel.

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