United States Patent

Eickenhorst

[15] **3,635,069**

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[54] DRIVE MECHANISM FOR MULTIPLE PLUNGERS

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[73] Assignee: **Dayton Reliable Tool & Mfg. Company,** Dayton, Ohio

[22] Filed: **Nov. 5, 1969**

[21] Appl. No.: **874,242**

[52] **U.S. Cl.**.....**72/349,** 72/349, 72/361, 113/7 R

[51] **Int. Cl.**.....**B21d 51/26**

[58] **Field of Search** 113/7, 120, 115; 72/94, 349, 72/344–346, 361

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[57] **ABSTRACT**

A massive power-driven rotary structure has a plurality of circumferentially spaced pairs of dies to process a corresponding plurality of workpieces on each of its revolutions. One die of each pair is mounted on a longitudinally extending plunger and all of the plungers are reciprocated in sequence by a fixed circumferential cam track adjacent one end of the structure.

13 Claims, 18 Drawing Figures

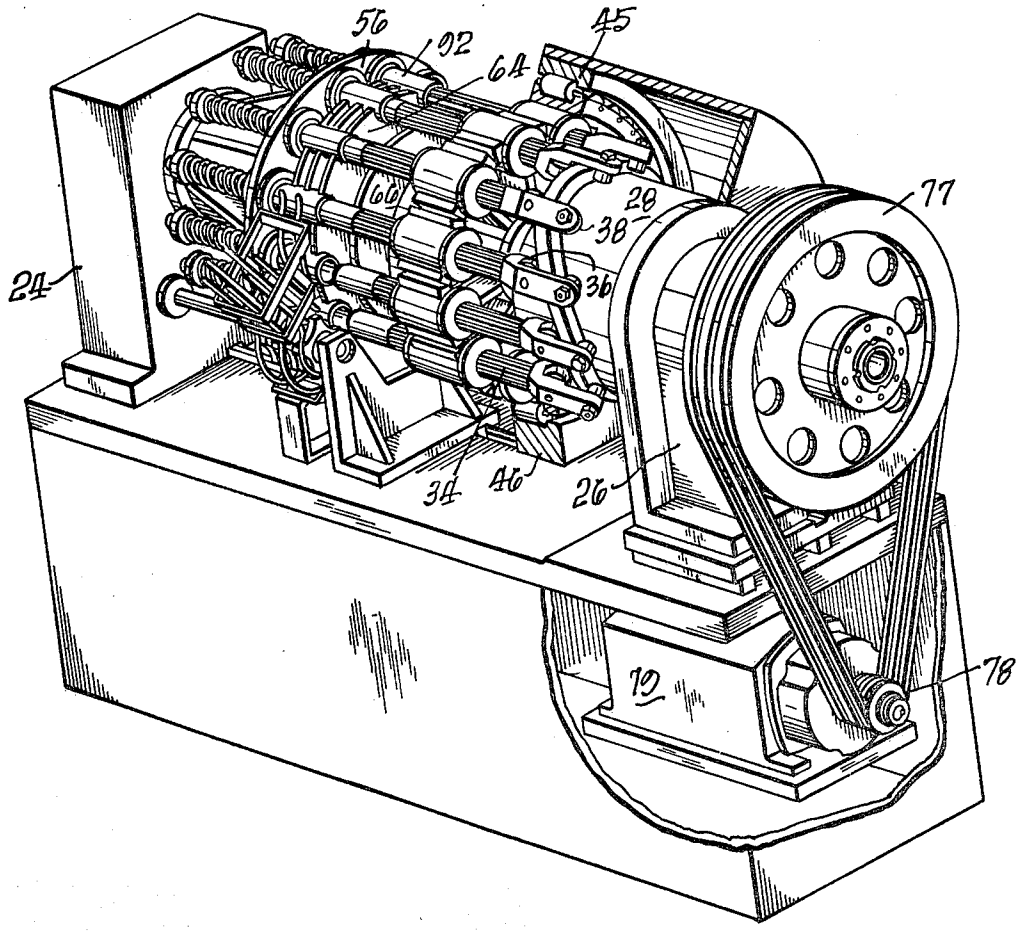


FIG-1

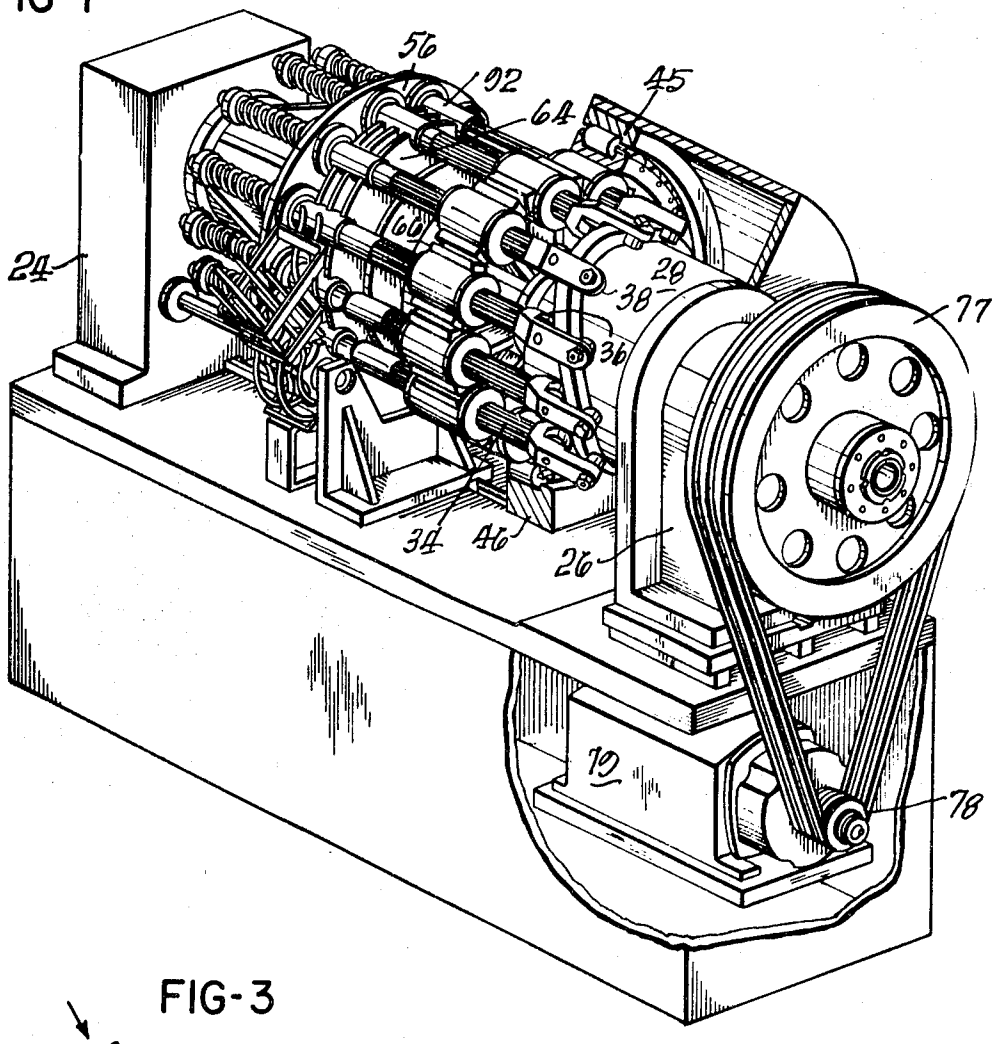
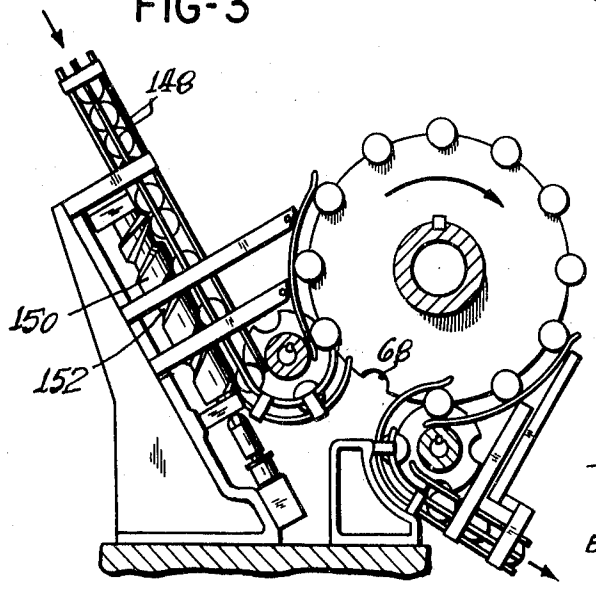


FIG-3



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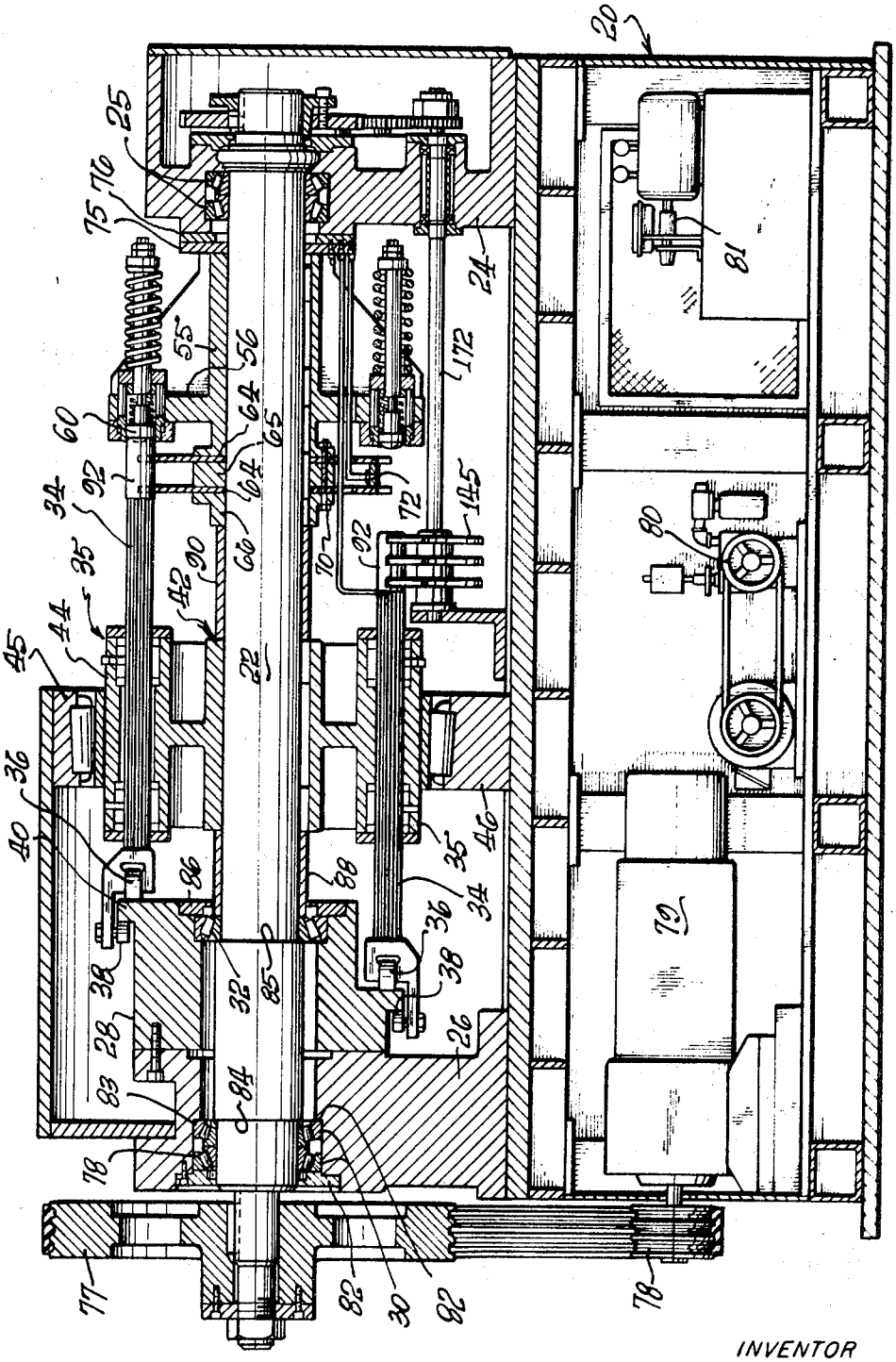


FIG-2

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FIG-4

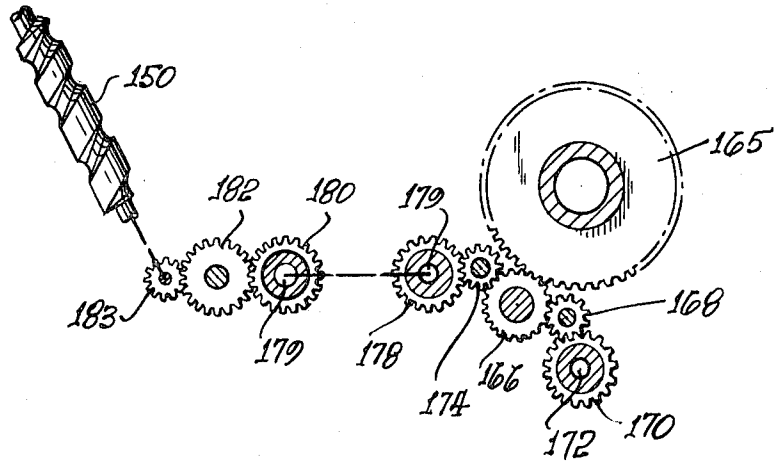


FIG-5

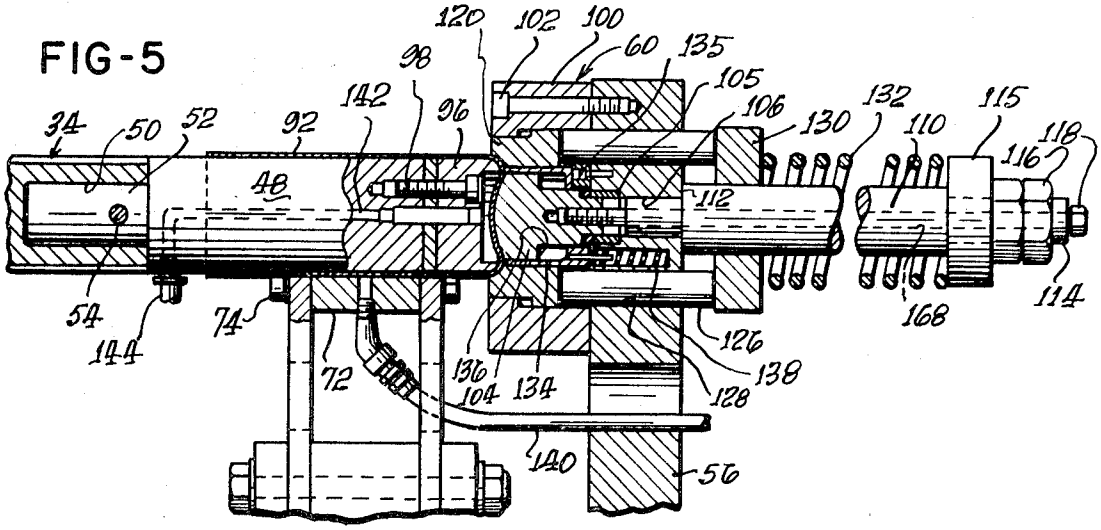
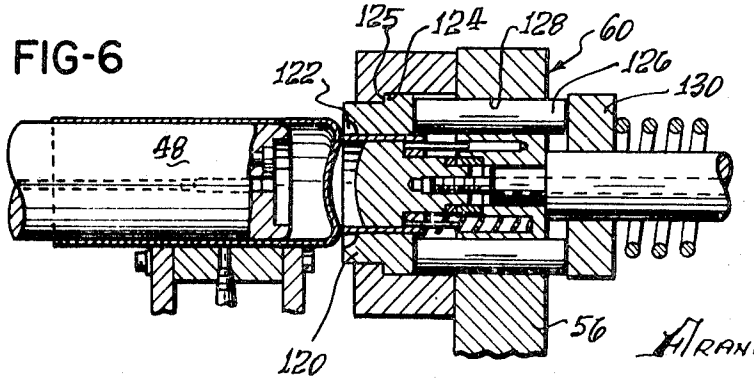


FIG-6



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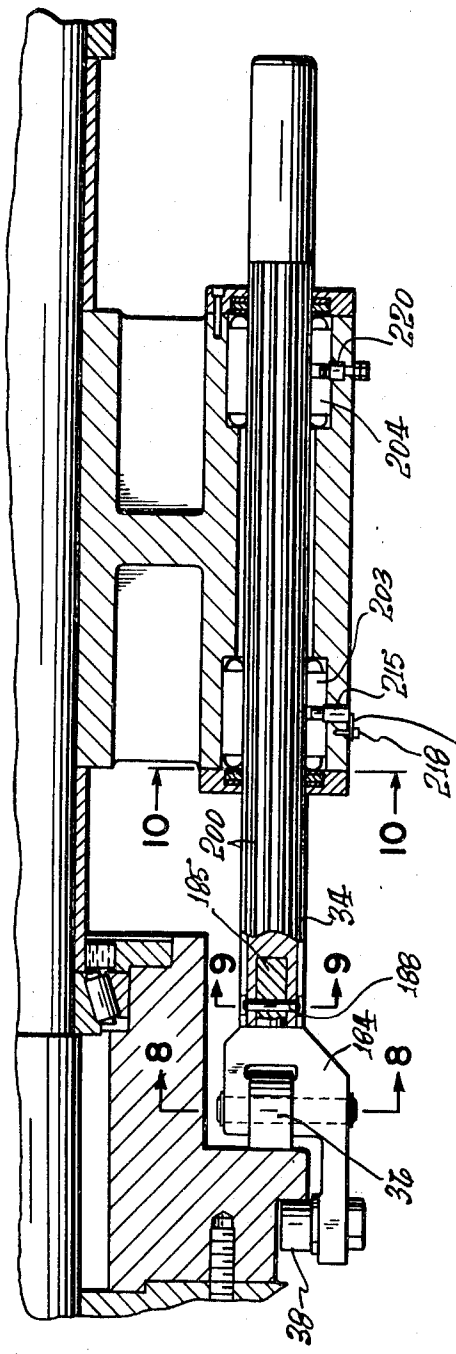


FIG-7

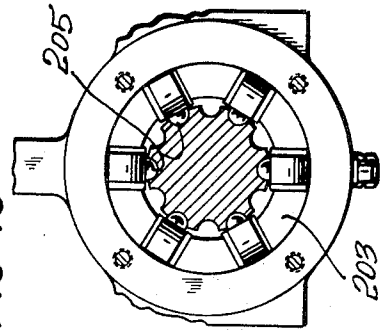


FIG-10

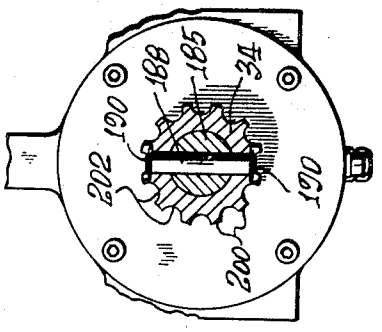


FIG-9

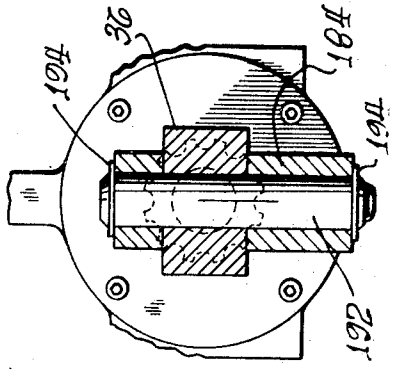


FIG-8

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FIG-11

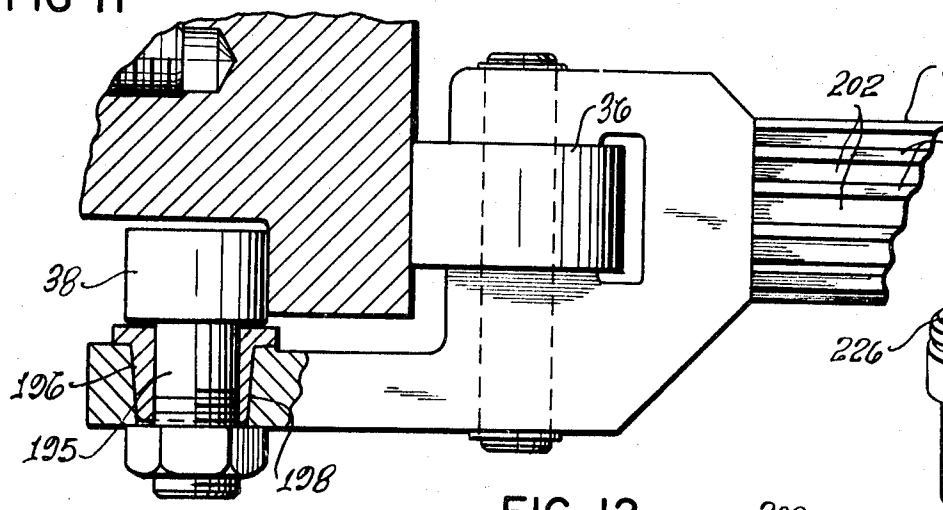


FIG-13

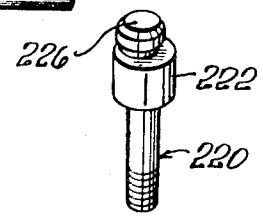


FIG-12

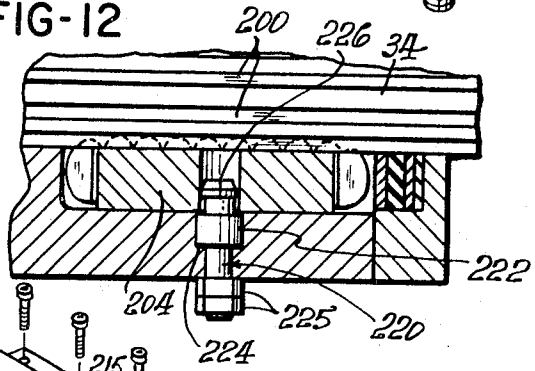


FIG-14

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FIG-15

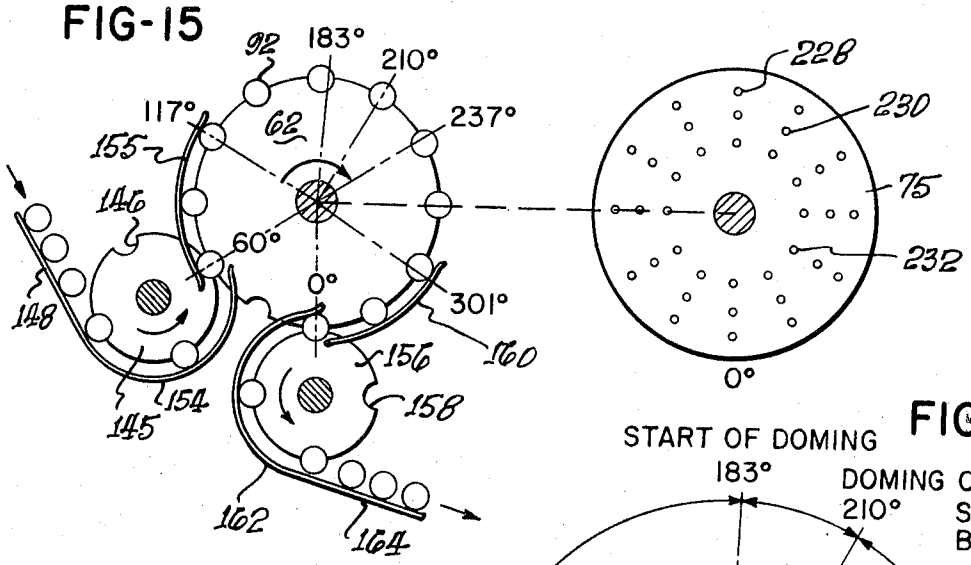


FIG-16

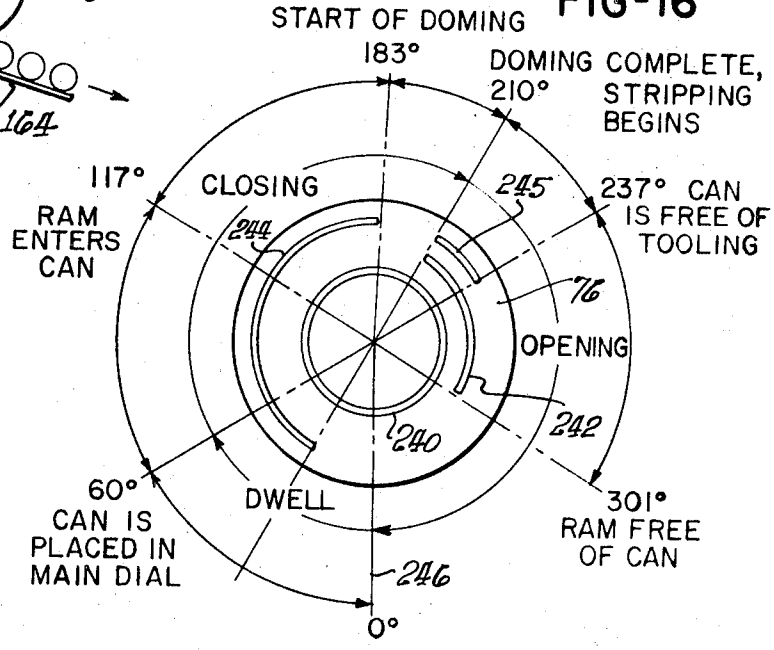


FIG-17

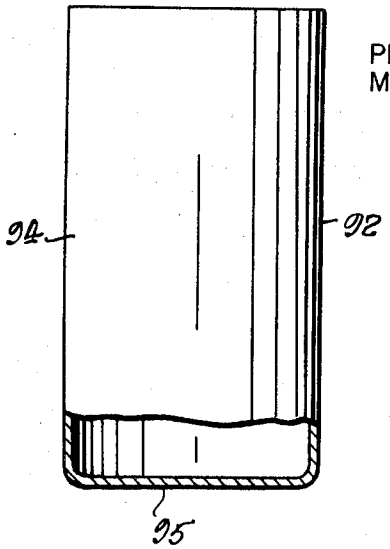
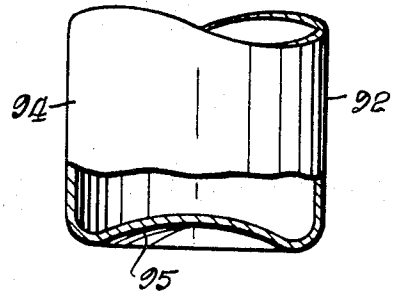


FIG-18



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DRIVE MECHANISM FOR MULTIPLE PLUNGERS

BACKGROUND OF THE INVENTION

The invention is directed to certain problems that are encountered in designing a mechanism for the mass processing of workpieces by cooperating dies where die-operating forces of relatively high magnitude are required coupled with the requirement for a high degree of accuracy in the operation of the dies. If high-magnitude actuating forces are required such a mechanism is necessarily relatively heavy and one problem is to obtain a high-production rate by means of such a massive apparatus.

Another problem arises from the fact that a high rate of production with a relatively massive mechanism involves inertia forces of high magnitude that make it difficult to operate the mechanism with sufficient speed for an economically high rate of hourly production.

A further problem to be taken into consideration arises from the desirability of such a massive high-speed apparatus to be versatile for the processing of a wide range of workpieces to justify the high-investment cost, it being especially important to minimize the downtime required for change over from one run of workpieces to a run of different workpieces.

Another problem to which the preferred embodiment of the invention is specifically directed is the problem of arranging a high-speed production mechanism which will handle extremely flimsy workpieces such as workpieces in the form of exceedingly thin cylindrical shells of aluminum alloy.

As will be explained, other problems pertinent to the invention arises from the use of a massive power-driven rotary structure having a plurality of pairs of dies that operate in sequence in the course of each revolution of the structures.

SUMMARY OF THE INVENTION

The preferred embodiment of the invention employs a power-actuated massive rotary structure of substantial axial dimension with a plurality of pairs of dies circumferentially spaced thereon for operation in sequence on each revolution of the structure. One die of each pair of dies is fixedly mounted on the rotary structure and the other die of the pair is mounted on a longitudinally extending plunger which reciprocates in a corresponding longitudinal guideway on the rotary structure and each of the plungers is provided with followers that cooperate with a fixed cam track adjacent one end of the rotary structure. In the initial embodiment of the invention, 12 pairs of dies are actuated through their operating cycles on each revolution of the rotary structure so that the rate of production is 12 times the rate of rotation of the rotary structure.

In contrast to a conventional punch press, the major part of the mass of the working mechanism rotates continuously at a constant rate and thus eliminating the necessity for repeatedly accelerating and decelerating massive parts. The rotary structure that carries the 12 pairs of dies serves as a flywheel and the only reciprocating parts are the longitudinal plungers and the dies thereon. It is apparent then that the invention solves the problem of dealing with inertia forces. It is also apparent that the invention solves the problem of achieving high production with a massive mechanism since the plurality of circumferentially spaced pairs of dies multiply the rate of production.

The problem of adapting such a high-speed mechanism for precise die operations on flimsy thin-walled workpieces is solved largely by employing vacuum means to releasably anchor the flimsy workpieces at desired points in the operating cycle. In the preferred practice of the invention further provision is made for supplying compressed air between die parts and the workpieces to facilitate stripping of the workpieces from the dies.

A further feature of the preferred practice of the invention is the concept of employing commutator means for placing the rotary structure in communication with a stationary vacuum source, a stationary compressed air source and a stationary lubrication source.

It has been found to be exceedingly difficult to put this basic concept into commercial practice because actuating the circumferentially spaced dies in sequence by a fixed cam track may result in self-destruction of the apparatus if the high-magnitude forces are not properly controlled. The present embodiment of the invention is based on the discovery of the complicated cause of such self-destruction in prior mechanisms of this general type.

As will be explained, diversion of the high-magnitude operating forces into destructive channels is avoided by specific provisions to maintain with precision certain geometrical relationships which have been discovered to be absolutely essential.

The features and advantages of the invention will be understood by reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are to be regarded as merely illustrative:

FIG. 1 is a perspective view of the presently preferred embodiment of the invention;

FIG. 2 is a longitudinal axial sectional view of the embodiment;

FIG. 3 is a more or less diagrammatic view showing how workpieces are fed to the rotary structure at an input station and further showing how the finished workpieces are removed at an output station;

FIG. 4 is a diagrammatic view showing how the mechanisms at the input and output stations are operatively connected with the rotary structure for actuation thereby in synchronism therewith;

FIG. 5 is an enlarged fragmentary view partly in section and partly in side elevation showing how a pair of dies close to process a workpiece;

FIG. 6 is a similar view showing one die of the pair being retracted after the workpiece is processed;

FIG. 7 is an enlarged fragmentary view partly in section and partly in side elevation showing how one of the longitudinally extending plungers is mounted on the rotary structure and is operated by a stationary cam track;

FIGS. 8, 9 and 10 are enlarged cross sections taken as indicated by the lines 8—8, 9—9 and 10—10 respectively of FIG. 7;

FIG. 11 is a greatly enlarged fragmentary view partly in side elevation and partly in section showing the two follower rollers on a longitudinal plunger cooperating with the fixed cam track;

FIG. 12 is a sectional view showing how an eccentric stud may be employed to rotatably adjust a ball sleeve for the purpose of preloading a longitudinally extending plunger;

FIG. 13 is a perspective view of the eccentric stud;

FIG. 14 is an exploded perspective view showing how the longitudinally extending plungers are mounted on the rotary structure for quick removal and replacement;

FIG. 15 is a diagram showing a rotary disk of a commutator means and indicating how the rotary disk is operatively related to the main dial or turret that carries the successive workpieces;

FIG. 16 is a diagrammatic view of a complementary fixed disk of the commutator that cooperates with the commutator shown in FIG. 15;

FIG. 17 is a side elevation partly in section, showing a cup-shaped thin-walled aluminum workpiece, the bottom of which is to be dished or domed inwardly by the dies of the apparatus; and

FIG. 18 is a similar fragmentary view of the workpiece showing the result of the die operation.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIGS. 1 and 2, the selected embodiment of the invention has a hollow base, generally designated 20 and fixed support structure on the base to journal the axial shaft 22 of a

rotary structure that carries the tooling for processing successive workpieces. The fixed support structure includes an upright casting 24 that supports one end of the axial shaft 22 by means of a pair of opposed thrust bearings 25. At the other end of the axial shaft a pair of interconnected castings 26 and 28 support the shaft by means of a pair of opposed thrust bearings 30 and a third thrust bearing 32.

The rotary structure carries a plurality of circumferentially spaced longitudinally extending plungers 34 which reciprocate in corresponding guideways, generally designated 35, and which are provided with pairs of follower rollers 36 and 38. The casting 28 which is bolted on the casting 30 is formed with a continuous cam track 40 for cooperation with the follower rollers 36, 38 to reciprocate the plungers 34, the cam track being in the form of a circumferential rib of undulating configuration as required for reciprocating the plungers. The circumferential series of guideways 35 for the plungers 34 are incorporated in a guideway casting 42 that is keyed to the axial shaft 22 and that has an outer cylindrical surface 44 for cooperation with a surrounding bearing 44. The bearing 45 is mounted in an upright support casting 46 and thus serves to stabilize the guideway casting 42 as required for guidance of the plungers 35 with a high degree of precision.

As indicated in FIG. 5 a suitable die 48 is mounted on the outer end of each plunger 34 and for this purpose each plunger has an end socket to receive a shank portion 52 of the die with the shank portion releasably secured by a diametrical dowel 54.

Also keyed to the axial shaft 22 is a tool support casting 55 having a radial flange 56 with a circumferential series of apertures therein to receive a second set of dies or die assemblies, generally designated 60, which are paired with the first-mentioned dies 48 for cooperation therewith in the processing of workpieces.

Also keyed to the axial shaft 22 is a main star wheel, generally designated 62, which serves as a turret to carry the successive workpieces while the workpieces are being processed by the dies. As shown in FIG. 1, the star wheel 62 comprises two disks 64 with a spacer collar 65 between the two disks, and with a hub member 66 abutting one of the disks. Each of the two disks 64 is of the configuration of a star wheel that provides a circumferential series of arcuate recesses 68, the recesses of the two disks being paired to form seats to receive the successive workpieces. As indicated in FIG. 1, the two disks 64 and the associated castings are tied together by suitable bolts 70 and, as best shown in FIG. 5, a spacer block 72 and a cooperating bolt 74 tie the two disks 64 together in the region of each of the pairs of arcuate recesses 68 to cooperate with the pair of recesses to form the seat for a workpiece.

As shown in FIG. 1, two components of a commutator means are arranged at one end of the axial shaft 22. One of these components is a commutator disk 75 that is keyed to the shaft for rotation therewith and the other component is a fixed coaxial disk 76 that is anchored to the end casting 24.

The axial shaft 22 carries a flywheel 77 which serves as a driven pulley, the flywheel being connected by a belt with a drive pulley 78 on the shaft of a motor 79. The motor is housed by the hollow base 20 along with a motor-driven vacuum pump 80 and a motor-driven oil pump 81.

All of the various components on the axial shaft 22 are preloaded to keep the various components in constant arcuate relationship with each other. For this purpose an outer race of one of the two thrust bearings 30 at one end of the shaft abuts a keeper ring 82 that is bolted to the support casting 26 and the outer race of the second thrust bearing 30 bears against an inner circumferential shoulder 83 of the casting. The axial shaft 22 is formed with a circumferential shoulder 84 that abuts the inner race of the second thrust bearing 30 and an oppositely facing circumferential shoulder 85 of the axial shaft abuts the inner race of the thrust bearing 32. The outer race of the thrust bearing 32 is retained by a keeper ring 86 that is bolted to the casting 28. The spacer sleeve 88 embraces the shaft 22 between the inner race of the thrust bearing 32 and one end of the guideway casting 42 and a second spacer sleeve 90 is interposed between the guideway casting and the hub member 68 of the star wheel assembly 62. As heretofore stated the star wheel assembly 62 abuts the tool support casting 55 and the tool support casting in turn abuts the rotary commutator disk 75 which presses the second fixed commutator disk 76 against the support casting 24.

For the purpose of exemplifying the utility of the illustrated embodiment of the invention, the embodiment will be described as adapted to process workpieces 92 of the character shown in FIG. 17. Each workpiece 92 is a cup-shaped aluminum shell having a circumferential wall 94 and a bottom wall 95. The workpiece is made of a suitable aluminum alloy and after leaving the described apparatus the workpiece is further processed to eventually become the body of a beverage container. The workpiece is flimsy because its walls are relatively thin, the cylindrical wall 94 being, for example, as thin as 0.006 inch midway between the two ends of the workpiece. The particular operation that is performed at a high-rate per minute by the die means of the apparatus is the transformance of the bottom wall 95 to the configuration shown in FIG. 18 which may be described as an inwardly domed configuration.

The die 48 on the leading end of each plunger 34 is dimensioned to telescope into a workpiece 92 as shown in FIG. 5 and as also shown in FIG. 5 the die 48 has a removable nose 96 that is releasably secured by screws 98. The nose 96 has a concave-working face conforming to the configuration of the bottom wall of the workpiece that is shown in FIG. 18.

As shown in FIG. 5, the cooperating die assembly 60 includes a retaining ring 100 that is releasably anchored by screws 102 to the radial flange 56 of the tool support casting 55. The die assembly 60 further includes a doming die 104 that has a convex nose to "dome" the bottom wall of the workpiece and has a shank by which it is immobilized relative to the radial flange 56 of the tool support casting in which the die assembly is mounted.

In the construction shown, the doming die 104 backs against a spacer ring 105 which in turn backs against a circumferential shoulder formed in a bore 106 of the radial flange 56. The degree to which the bottom wall of the workpiece is domed is determined by the length of the spacer sleeve. The doming die 104 is secured by a tie rod 108 that is threaded into the shank portion of the die and that extends outward through a tubular rod 110. The tubular rod 110 has a reduced end portion that extends into the bore 106 of the radial flange 56 and has a circumferential shoulder 112 that abuts the face of the radial flange. The tubular rod 110 further has an outer end portion 114 of reduced diameter to receive an outer collar 115 which is retained by a pair of nuts 116. A nut 118 on the outer end of the tie rod 108 is tightened against the outer end of the tubular rod to place the rod under tension and thus immobilize the tubular rod and the die 104.

The die assembly 60 includes an annular die member 120 which, as shown in FIG. 6, has an annular recess 122 to reshape the outer radial region of the bottom wall 95 of the cup-shaped workpiece just prior to the doming operation. The annular die member 120 further has a circumferential shoulder 124 to cooperate with an inner circumferential stop shoulder 125 of the retaining ring 100. For the purpose of urging the annular die member 120 outwardly of the die assembly, four smooth pins 126 are mounted in four corresponding bores 128 of the radial flange 56 and a collar 130 that is slidingly mounted on the tubular rod 110 is under pressure by a suitable heavy coil spring 132 that backs against the outer collar 115.

In the construction shown a thin cylindrical pressure pad 134 is interposed between the doming die 104 and the annular die member 120 to strip finished workpieces from the annular die member and for this purpose the thin pressure pad has a greater range of outer movement than the annular die 120. The pressure pad 134 is integral with a ring 135 which serves

as a stop in cooperation with a radial shoulder 136 of the die 104, and the ring is acted upon by a plurality of light springs 138 that urge the pressure pad outward.

A feature of the invention is the concept of employing a vacuum to releasably anchor the successive workpieces 92 in the peripheral seats of the main star wheel 62. As shown in FIG. 5 this purpose is served by providing each of the spacer blocks 72 of the main star wheel with a radial bore which communicates with a tube 140 which in turn communicates with a suitable vacuum source by means including the previously mentioned two commutator disks 75 and 76. A further feature of this particular embodiment of the invention is the concept of supplying compressed air to the various dies 48 to strip the finished workpieces from the dies 48. As indicated in FIG. 5, each die 48 is formed with an axial passage 142 which receives compressed air from a corresponding tube 144.

As indicated in FIGS. 3 and 15, the successive workpieces are fed to the main star wheel 62 by means including a smaller input star wheel of the same general construction as the main star wheel, the input star wheel having four circumferentially spaced peripheral seats 146 to convey the workpieces to the 12 peripheral seats of the main star wheel 62. As shown in FIG. 3 a plurality of rails 148 form a feed chute that leads to the input star wheel 145 and, in a well-known manner, a screw member 150 extending longitudinally of the chute is formed with a spiral groove 152 to control the downwardly moving workpieces. The pitch angle of the spiral groove 152 progressively increases for the purpose of progressively spreading the workpieces apart until the workpieces are spaced in accord with the circumferential spacing of the seats 146 of the input star wheel 145.

As indicated in FIG. 15 arcuate guard rails 154 extend under the input star wheel to keep the workpieces in the seats 146 until the workpieces reach the main star wheel 62. The main star wheel is provided with additional arcuate guardrails 55 in the region of the input star wheel to retain the successive workpieces 92 in their seats on the main star wheel until a vacuum is developed at each seat of the main star wheel to effectively retain the workpieces.

Also associated with the main star wheel 62 is a smaller output star wheel 156 having a series of four peripheral seats 158 for the processed workpieces. Arcuate guardrails 160 in the region of the output star wheel hold the workpieces in their seats in the main star wheel after vacuums of the seats are terminated, the guardrails keeping the processed workpieces in place until they reach the output star wheel 56. Additional rails 162 retain the finished workpieces in the seats 158 of the output star wheel and provide a gravity chute 164 for a discharge of the finished workpieces.

The input star wheel 145 and the output star wheel 156 are operatively connected to the rotary structure by suitable gearing and since the main star wheel 62 has 12 peripheral seats and each of the smaller star wheels has only four peripheral seats, the two star wheels are actuated at three times the r.p.m. of the larger star wheel.

Suitable gearing for this purpose is shown diagrammatically in FIG. 4 where a large gear 165 unitary with the rotary structure serves as a drive gear in mesh with a smaller driven gear 166. The driven gear 166 meshes with an idler pinion 168 which in turn meshes with a gear 170 on a shaft 172 that carries the output star wheel 156. In like manner, the driven gear 166 meshes with an idler gear 174 which in turn meshes with a gear 178 on a counter shaft 179 that is shown in FIG. 2. The shaft 179 drives the input star wheel 145 as shown in FIG. 1. In addition, the shaft 179 carries a gear 180 which acts through two gears 182 and 183 to drive the previously described input screw member 150.

The invention includes the discovery of the vital fact, heretofore unknown, that unless certain critical relationships are precisely maintained, the various plungers 34 are subject to disruptive forces that either wreck the means for mounting follower rollers on the plungers or rupture the fixed cam track 40. These relationships are: first, that the opposite faces of the cam track 40 be in cross section precisely perpendicular to the axis of rotation of the shaft 22; second, that the axis of rotation of each of the two follower rollers 36 and 38 lie precisely at the intersection of two planes, one plane being perpendicular to the axis of rotation of the shaft 22 and the other plane being a radial plane that includes the axis of rotation; third, that the various guideways 35 on the rotary structure for guiding the plungers 34 accurately and reliably maintain the plungers not only precisely parallel with the axis of rotation of the rotary structure but also at correct rotary positions on their longitudinal axes relative to the guideways for precisely correct orientation of the corresponding follower rollers 36 and 38; and fourth, that the two follower rollers 36 and 38 closely hug the opposite faces of the cam track throughout each revolution of each rotary structure. It is vitally essential that backlash be eliminated to maintain these relationships.

The structural provisions for reliably and accurately maintaining these relations will now be described. As shown in FIG. 7 the two follower rollers 36 and 38 of each plunger 34 are carried by a sturdy bracket 184 which has a shank 185 fitted snugly into an end socket of the plunger with a slightly tapered fit and the shank is securely anchored by a diametrical dowel 188. As indicated in FIG. 9, the two opposite ends of the dowel 118 are peened into engagement with corresponding locking washers 100.

As shown in FIGS. 7, 8 and 11, the follower roller 36 is mounted on the bracket 184 by means of an axle pin 192 that has a forced fit in the bracket and is peened at its opposite ends into engagement with corresponding lockwashers 194.

As best shown in FIG. 11, each of the follower rollers 38 is mounted on a stud 195 that extends through a rotatably adjustable flanged bushing 196, the exterior of the flanged bushing being conical to fit tightly in a conically tapered bore 198 in the bracket 184. The inner bore of the bushing 196 is eccentric relative to the outer circumference of the bushing so that the bushing may be rotated to shift the roller 38 snugly into contact with the cam track 40. Thus the adjustable eccentric bushing 196 makes it possible to preload the two rollers 36 and 38 in opposition to each other to eliminate any possibility of free play between the rollers and the cam track.

Each of the plungers 34 is of noncircular cross-sectional configuration and the corresponding guideway 35 is of complementary noncircular configuration to prevent rotation of the plunger on its axis and thus maintain the axis of the two follower rollers 36 and 38 in accurate radial alignment with the axis of rotation of the rotary structure. In this particular embodiment of the invention, each of the plungers 34 has a circumferential series of longitudinal splines 200 which form corresponding longitudinal grooves 202 (FIGS. 9 and 11) and the guideway 35 for each plunger includes a pair of engagement means in the form of sleeves 203 and 204 that are formed with complementary splines that extend into the longitudinal grooves 202. In the present embodiment of the invention each of the sleeves 203 and 204 is in the form of a ball nut which as indicated in FIG. 10 has a plurality of circumferentially spaced radially inward splines in the form of rows of balls 205 to engage the grooves 202.

As shown in FIGS. 7 and 14, the two ball nuts 204 are mounted in corresponding cylindrically curved seats 206 in the guideway casting 42 and the ball nuts are releasably secured by corresponding end caps 208 and a pillow block 210, the end caps being secured by suitable screws 212 and the pillow block being releasably held by suitable screws 214. As shown in FIG. 7, the sleeve 203 is anchored against rotation by a radial pin 215 that is releasably retained by a metal clip 216 which in turn is held in place by a screw 218. The rotary position of the ball nut 203 is accurately determined to cause the balls 205 of the ball nut to snugly abut corresponding splines 200 of the plunger 34 to oppose rotation of the plunger on its axis in one rotary direction out of its correct rotary position at which the axes of the two follower rollers 36 and 38 are accurately radially aligned relative to the axis of rotation of the rotary structure.

The second ball nut **204** is adjustable to permit it to be preloaded against the ball nut **203** thereby to accurately maintain the precisely correct rotary position of the plunger **34**. For this purpose, as best shown in FIGS. **12** and **13**, a stud **220** is mounted radially in the corresponding pillow block **210** and has a concentric cylindrical enlargement **222** which backs against a shoulder **224**. A pair of nuts **225** on the outer end of the stud may be tightened to releasably hold the stud against rotation. The stud **220** has a head **226** that extends from the enlargement **222** eccentrically thereof. Thus the stud **220** may be rotatably adjusted to cause the head **222** to serve as a crank for rotating the ball nut **204** in a direction to tighten the plunger **34** against the first ball nut **203**. This preloading of the two ball nuts in opposition to each other eliminates any loose play between the plunger and the two ball nuts.

As shown diagrammatically in FIG. **15**, the rotary disk **75** of the commutator means has three concentric rows of apertures, there being **12** apertures in each row. The apertures **228** of the outer row communicate with the 12 vacuum tubes **140** associated with the 12 seats of the main star wheel **62**; the 12 apertures **230** of the intermediate row are connected respectively to the previously mentioned tubes **144** that supply compressed air to the 12 dies **48**; and the apertures **232** of the innermost row are connected to corresponding tubes (not shown) for supplying lubricant to various working parts including the 12 die assemblies **60**.

As indicated in FIG. **16** the fixed disk **76** of the commutator means has concentric grooves corresponding to the three concentric rows of apertures in the rotary disk **75**. The innermost concentric groove **240** is in communication with the previously mentioned oil pump **81** to snugly lubricant which is sprayed on the cam follower rollers; a concentric arcuate groove **242** that cooperates with the intermediate row of apertures **230** of the rotary disk **75** is in communication with a suitable source of compressed air (not shown); a relatively long outer arcuate groove **244** and a shorter outer arcuate groove **245** register with the outermost apertures **228** of the rotary disk **75** and are in communication with the previously mentioned vacuum pump **80** in the hollow base **20**.

FIG. **16** indicates diagrammatically how the fixed commutator disk **76** is divided into sectors in relation to a radial reference line **246**. Reading clockwise from the radial reference line **246**, the first sector of 60° represents a dwell in the cam track **40** to cause each of the plungers **34** to pause at its fully retracted position to permit a new workpiece **92** to be placed in a peripheral seat **146** of the input star wheel **145**.

In the next sector which extends from 60° to 117°, a plunger **34** is advanced to cause the die **48** on the leading end thereof to telescope into a workpiece on the input star wheel **145**. The next sector from 117° to 183° represents the continued advance of each plunger **34** to move the corresponding workpiece **92** from its position on the input star wheel **45** to a peripheral seat on the main star wheel **62**. The continued advance of each plunger **34** represented by the sector 183°–210° causes the die **48** on the plunger to cooperate with the corresponding die assembly **60** to "dome" the workpiece, i.e., convert the bottom wall **95** of the workpiece to the configuration indicated in FIG. **18**. In the sector 210°–237°, the initial retraction of each plunger **34** occurs and at the same time compressed air is supplied to the corresponding die **48** to urge the finished workpiece against the die assembly **60** to strip the workpiece from the die **48** and leave the workpiece free on its seat on the main star wheel **62**.

When an advancing plunger **34** carries a workpiece **92** from the input star wheel **145** to a seat on the main star wheel **62**, the newly arrived workpiece is held in the seat mechanically by the arcuate guardrail **155** as indicated in FIG. **15**. While the workpiece is within the range of the arcuate guard **155**, the arcuate groove **244** of the fixed commutator disk **76** causes a vacuum to be created at the corresponding seat of the main star wheel to keep the workpiece on the star wheel after the workpiece clears the guardrail **155**. As may be seen in FIG. **16**, this vacuum is maintained until the start of the doming operation whereupon the vacuum terminates to give the workpiece freedom during the doming operation. After the doming operation when the plunger **34** initially retracts and when compressed air is supplied by the arcuate groove **242** for stripping the workpiece from the die **48**, the short arcuate groove **245** creates a vacuum to tend to hold the workpiece on its seat on the main star wheel thereby to cooperate in the stripping of the workpiece from the retracting plunger.

It may be readily understood that although the described apparatus is relatively massive, the heavy rotary structure is rotated continuously so that the whole mass of the rotary structure serves as a flywheel in addition to the flywheel **77**. Thus no problem arises from the inertia of the heavy structure, the only inertia forces being associated with the relatively lightweight plungers **34** and the dies thereon. With the rotary structure rotating, for example, at 100 r.p.m. and with 12 workpieces processed on each revolution of the rotary structure, the apparatus has a production rate of 1,200 pieces per minute to justify its initial cost.

The fact that the apparatus is highly versatile may be understood when it is considered that the dies **48** on the ends of the plungers may be readily replaced by another set of dies and, in like manner, the die assemblies **60** may be readily replaced. It is a simple matter to replace any one of the plungers **34** by simply removing the corresponding end caps **208** and the corresponding pillow block **210**.

My description in specific detail of the presently preferred embodiment of the invention will suggest various changes, substitutions and other departures within the spirit and scope of my invention.

I claim:

1. In an apparatus of the character described, the combination of:
- a fixed structure;
- a power-actuated rotary structure adjacent the fixed support structure;
- a plurality of longitudinally extending guideways mounted on the rotary structure and spaced circumferentially thereof;
- a corresponding plurality of longitudinally extending plungers mounted in the guideways respectively, each of said plungers having a working end and a trailing end;
- fixed cam means on the fixed structure positioned concentrically of the series of plungers and forming two opposite continuous cam walls;
- two follower means mounted on the trailing ends of the respective plungers in moving contact with said two cam walls respectively, said cam walls being shaped to reciprocate the plungers in said guideways in the course of each revolution of the rotary structure;
- a corresponding plurality of first die means mounted on the leading ends of the plungers respectively for movement therewith;
- a corresponding plurality of second die means paired with the first die means respectively and mounted on the rotary structure in alignment with the first die means for cooperation therewith to process successive workpieces;
- means to feed successive workpieces to said pairs of dies;
- means to remove the successive processed workpieces;
- said guideways and corresponding plungers being of complementary noncircular cross-sectional configuration to prevent rotation of the plungers on the axes; and
- a pair of cooperating engagement means incorporated in each of said guideways in engagement with the periphery of the corresponding plunger to oppose rotation of the plunger on its axis in opposite rotary directions respectively,
- said two-cooperating engagement means being preloaded against each other to keep the plungers from rotating on their axes and in doing so to minimize backlash between the plungers and the corresponding guideways.

2. A combination as set forth in claim 1 in which each of said plungers together with the corresponding followers, the

corresponding die means and the corresponding pair of engagement means is removable as a unit to permit one unit to be substituted for another.

3. A combination as set forth in claim 2 in which the pair of cooperating engagement means of the unit comprises two guide sleeves and in which the two guide sleeves are releasably attached to the rotary structure to releasably anchor the unit thereto.

4. A combination as set forth in claim 3 which includes means on the rotary structure to releasably engage the two sleeves of each unit to cause relative rotation between the two sleeves to preload the two sleeves against each other.

5. A combination as set forth in claim 1 in which one cooperating engagement means of each pair is a sleeve of an inner circumferential configuration complementary to the cross-sectional configuration of the corresponding plungers,

said sleeve being rotatably preloaded relative to the other engagement means to cooperate therewith to prevent rotation of the corresponding plunger on its axis and to eliminate backlash between the plunger and the corresponding guideway.

6. A combination as set forth in claim 5 in which each of said plungers is formed with a plurality of longitudinal splines and each of said engagement means has a plurality of longitudinal spline means in engagement with the splines of the corresponding plunger.

7. A combination as set forth in claim 5 in which each of said sleeves is in the form of a ball nut, each of said ball nuts having at least one spline means in the form of a longitudinal row of balls.

8. A combination as set forth in claim 5 in which said two continuous cam walls in cross section are precisely perpendicular to the axis of rotation of the rotary structure;

in which the follower means on the trailing end of each plunger comprises two rollers in contact with the two cam walls respectively with the axis of rotation of each roller located precisely at the intersection of two planes, one plane being perpendicular to the axis of rotation of the rotary structure, the other plane including the axis of rotation; and

in which one of said cooperating engagement means of each pair serves as a stop against rotation of the plunger on its axis beyond a given rotary position at which the axis of rotation of each roller is precisely located at the intersection of the two corresponding planes, the other engagement means of each pair urging rotation of the corresponding plunger on its axis against the stop to maintain the plunger at said given rotary position.

9. A combination as set forth in claim 1 in which the portion of the rotary structure that includes the plurality of guideways is surrounded by fixed support structure with a bearing interposed between said portion and the surrounding fixed structure to stabilize said portion to promote accuracy in the operation of the pairs of die means.

10. In an apparatus of the character described wherein a cylindrical cam body with a transverse end wall is first mounted with its cylindrical wall in a seat of a rotary holder, then a plunger enters the cylindrical can body to cooperate with die means for processing the can body and, finally, the plunger is withdrawn to leave the processed can body in the seat,

the improvement comprising:

a commutator united with the holder to rotate therewith, said commutator being in communication with a vacuum source and a compressed air source, fluid passage means controlled by the commutator to create a vacuum in said seat adjacent the cylindrical can body to hold the can body in the seat while the plunger enters the can body and subsequently to create a vacuum in the seat to hold the can body on the seat to facilitate disengagement of the plunger from the can body when the plunger is withdrawn from the can body; and

fluid passage means controlled by the commutator to discharge compressed air into the can body through the plunger to further facilitate disengagement of the plunger from the can body when the plunger is withdrawn from the can body.

11. An improvement as set forth in claim 10 in which the commutator includes fluid passage means to supply lubricant to moving parts that rotate with the holder.

12. A combination as set forth in claim 1 which includes adjustable means to tighten one of said two follower means against the corresponding cam wall to preload the two follower means for the elimination of backlash.

13. A combination as set forth in claim 1 in which the two follower means on the trailing end of each plunger comprises two rollers in contact with the two cam walls respectively;

in which each of the pairs of cooperating engagement means on each of said guideways comprises two guide sleeves embracing the corresponding plunger,

one of the two guide sleeves being held against rotation in a given rotary direction at a given rotary position,

the other of said two guide sleeves being adjustable to urge rotation of the plunger in said given rotary direction against the resistance of the one guide sleeve whereby to place the plunger at a given rotary position corresponding to the given rotary position of one sleeve,

said given rotary position of the plunger placing the axis of rotation of each of said two rollers precisely at the intersection of two planes, one plane being perpendicular to the axis of rotation of the rotary structure, the other plane including the axis of rotation.

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