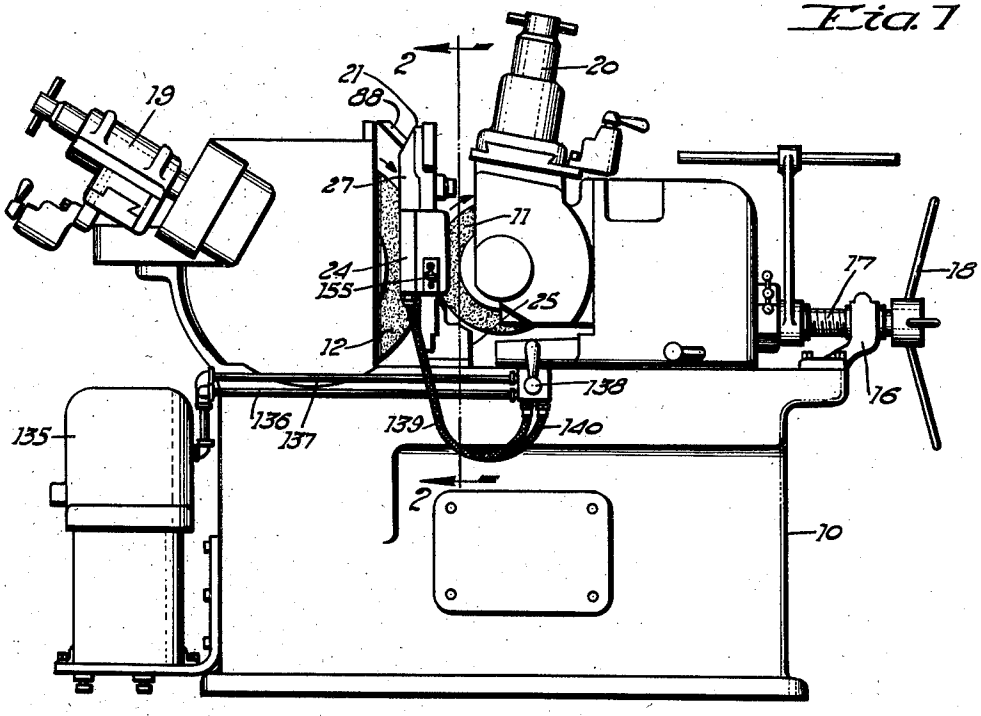
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GRINDING MACHINE AND METHOD OF GRINDING

Filed Dec. 24, 1942 4 Sheets-Sheet 1

Fig. 7



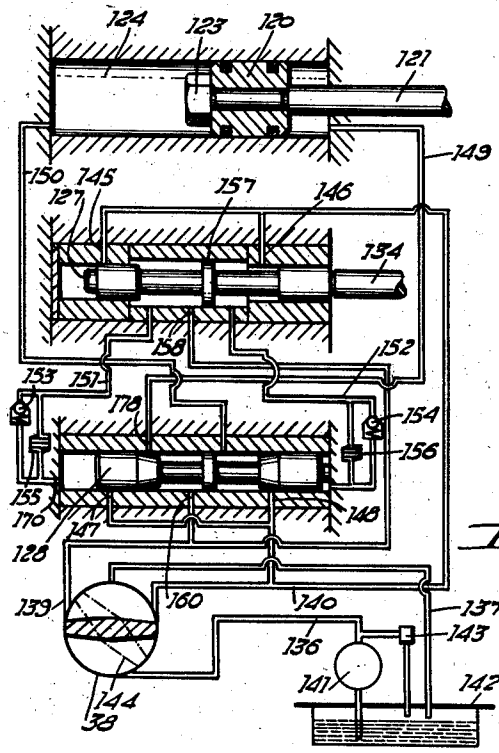


Fig. 8

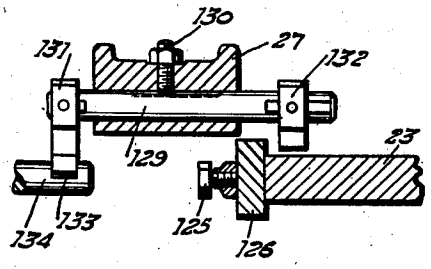


Fig. 7

BY

INVENTORS
Frederick J. Theler
George W. Binns
Jacob Decker
Blair, Curtis & Hayward
ATTORNEYS

June 12, 1945. F. J. THELER ET AL 2,377,982

GRINDING MACHINE AND METHOD OF GRINDING

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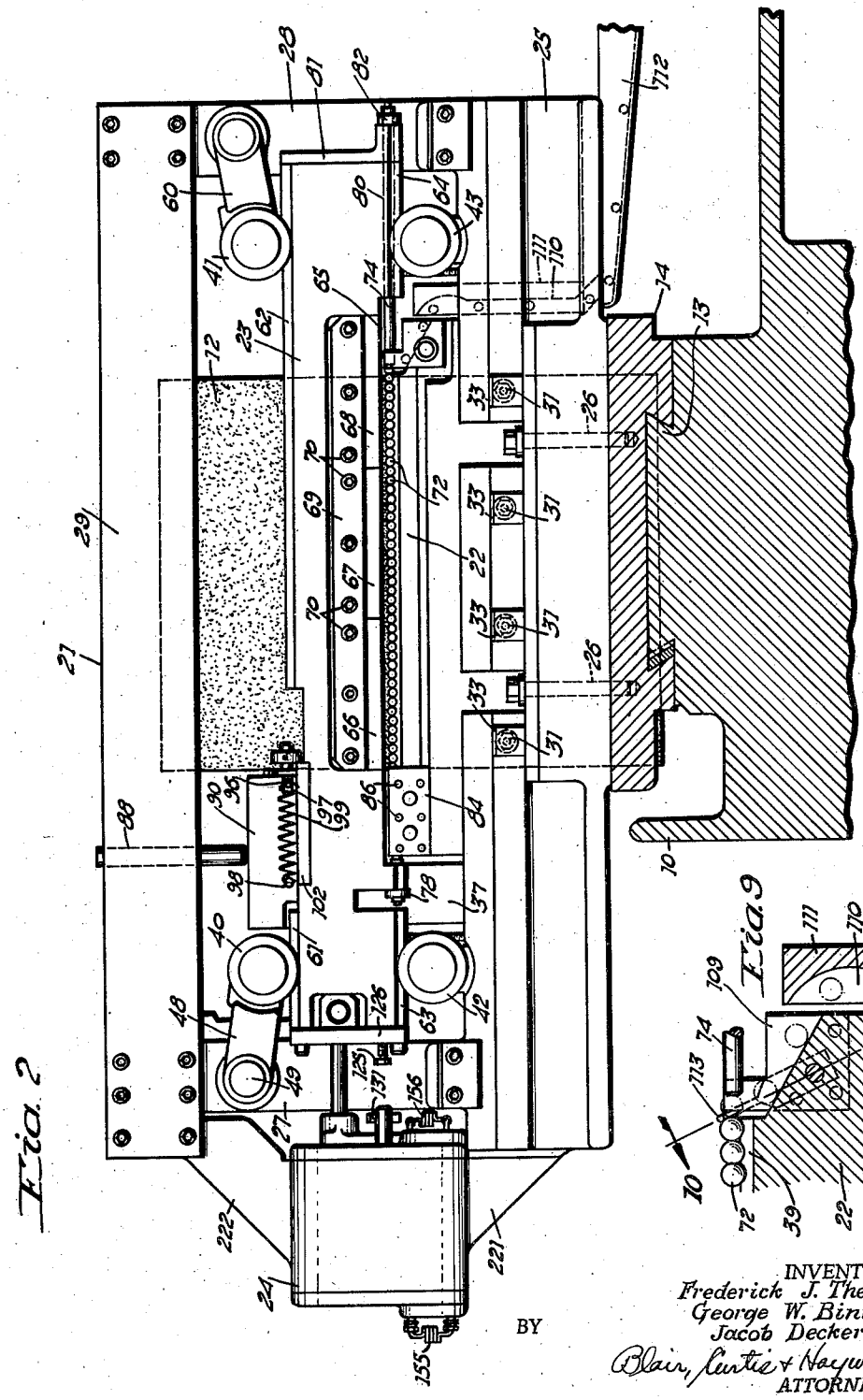


Fig. 2

Fig. 9

INVENTORS
Frederick J. Theler
George W. Binns
Jacob Decker

BY Blair, Curtis & Hayward
ATTORNEYS

June 12, 1945. F. J. THELER ET AL 2,377,982

GRINDING MACHINE AND METHOD OF GRINDING

Filed Dec. 24, 1942 4 Sheets-Sheet 3

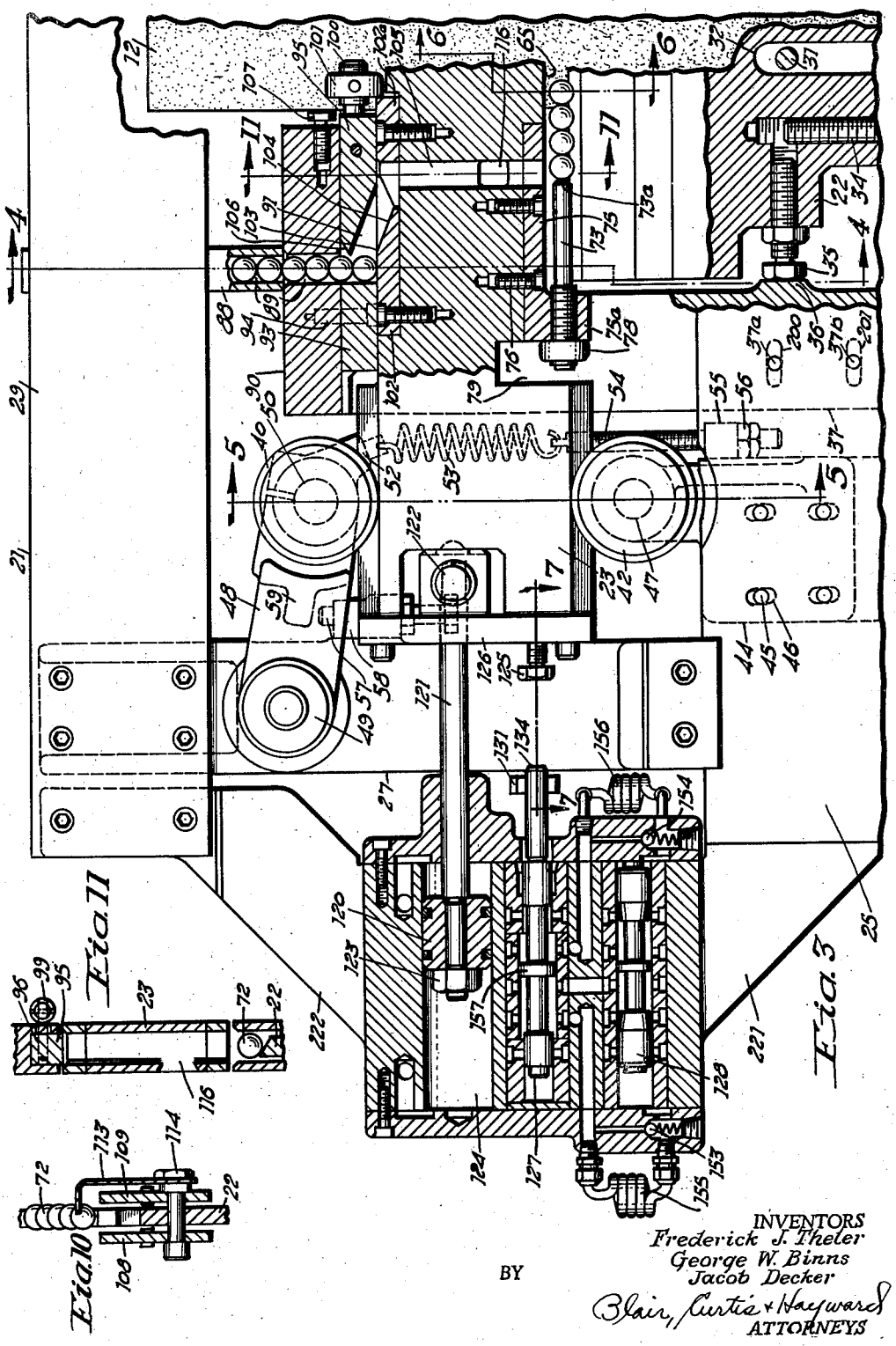


Fig. 11

Fig. 10

Fig. 3

INVENTORS
Frederick J. Theler
George W. Binns
Jacob Decker

BY Blair, Curtis & Hayward
ATTORNEYS

June 12, 1945. F. J. THELER ET AL 2,377,932

GRINDING MACHINE AND METHOD OF GRINDING

Filed Dec. 24, 1942 4 Sheets-Sheet 4

Fig. 4

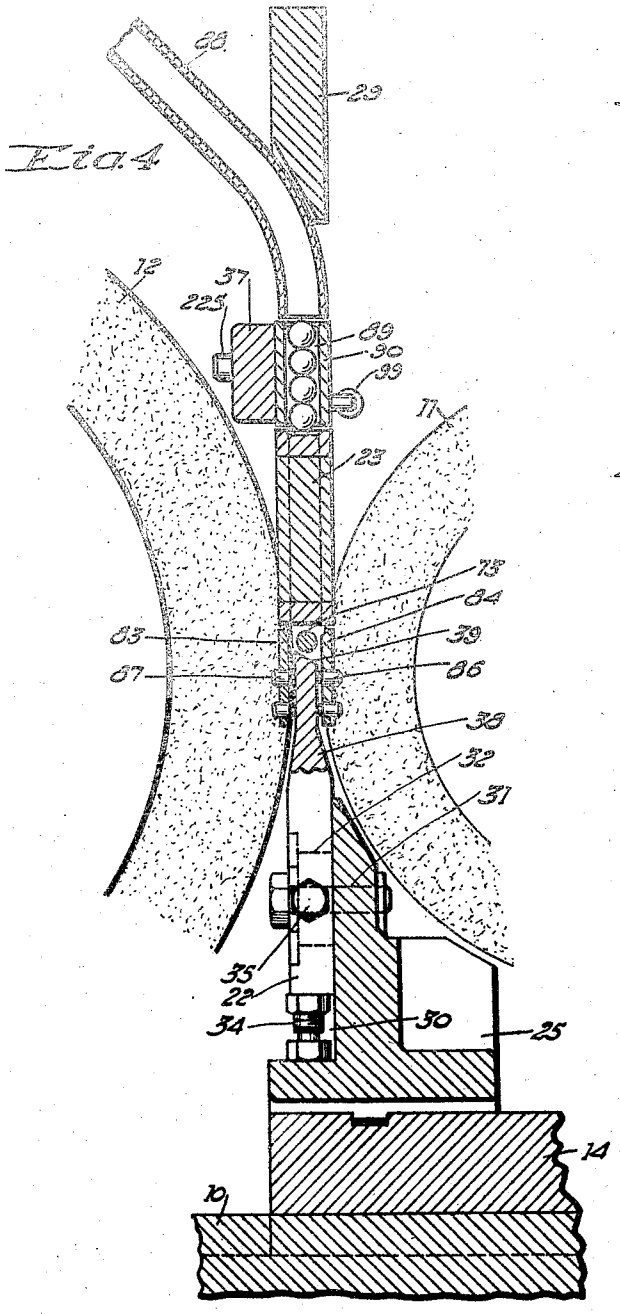


Fig. 5

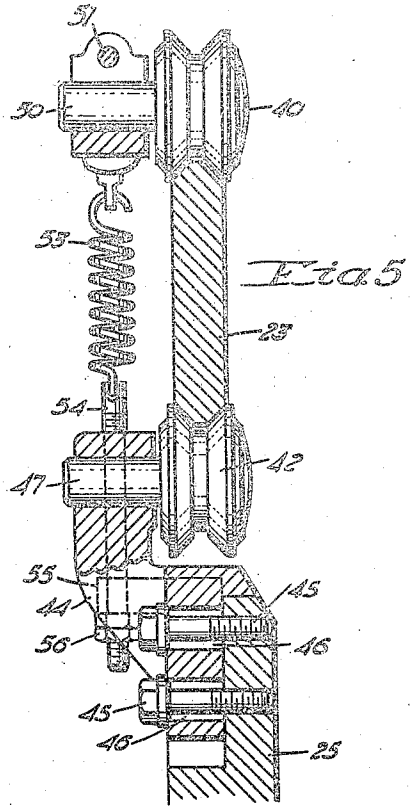
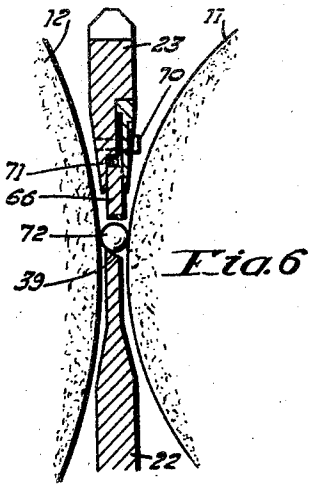


Fig. 6



INVENTORS
Frederick J. Theler
George W. Binns
Jacob Decker

BY Blair, Curtis & Hayward
ATTORNEYS

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UNITED STATES PATENT OFFICE

2,377,982

GRINDING MACHINE AND METHOD OF GRINDING

Frederick J. Theler, George W. Binns, and Jacob Decker, Cincinnati, Ohio, assignors to The Cincinnati Milling Machine Co., Cincinnati, Ohio, a corporation of Ohio

Application December 24, 1942, Serial No. 470,314

26 Claims. (Cl. 51—74)

This invention relates to grinding machines and a method of grinding.

One of the objects of this invention is to provide a simple, thoroughly practical and durable grinding machine for accurately and economically grinding balls. Another object is to provide a construction of the above character which is well adapted to withstand continuous hard use and which employs the centerless grinding principle. Another object is to provide a practical ball grinding attachment which may be applied to standard centerless grinding machines. Another object is to provide an economical and efficient method of accurately grinding balls in a centerless grinding machine. Other objects will be in part obvious and in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, arrangements of parts, and in the several steps and relation and order of each of the same to one or more of the others, all as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings in which is shown one of the various possible embodiments of this invention,

Figure 1 is an elevational view of the machine;

Figure 2 is a vertical sectional view taken on the line 2—2 of Figure 1, certain parts of the machine being removed for purposes of clarity;

Figure 3 is an enlarged view of the left-hand portion of Figure 2, certain of the parts thereof being broken away for purposes of clarity;

Figure 4 is a vertical sectional view taken on line 4—4 of Figure 3;

Figure 5 is a vertical section taken on the line 5—5 of Figure 3;

Figure 6 is a vertical section taken on the line 6—6 of Figure 3;

Figure 7 is a horizontal section taken on the line 7—7 of Figure 3 showing the pilot valve tripping mechanism;

Figure 8 is a diagrammatic view of the hydraulic control support;

Figure 9 is a vertical sectional view, on an enlarged scale, of that portion of Figure 2 where work is ejected from the grinding throat of the machine;

Figure 10 is a vertical sectional view taken on the line 10—10 of Figure 9; and,

Figure 11 is a vertical sectional view taken on the line 11—11 of Figure 3.

Similar reference characters refer to similar parts throughout the several views of the drawings.

Referring now to Figure 1, the machine includes a bed 10 having a regulating wheel 11 and grinding wheel 12 mounted thereon. On the right-hand portion of the machine bed, as viewed in Figure 1, surface ways 13 (Figure 2) support a carriage 14 which is thus movable longitudinally of the bed; carriage 14 supports the regulating wheel 11 and associated mechanism. A bracket 16 secured to the right-hand portion of the machine bed (Figure 1) carries a swivel nut (not shown) keyed thereto. A threaded shaft 17 connected to carriage 14 is threaded through the swivel nut and has a hand wheel 18 secured to its outer end. Accordingly movement of hand wheel 18 moves the carriage 14 and wheel 11 (Figure 2) longitudinally of the machine to adjust the distance between the regulating and grinding wheels as desired.

Grinding wheel 12 and regulating wheel 11 are provided with suitable truing mechanisms, generally indicated at 19 and 20, for truing the active opposed surfaces of the wheels. Grinding wheel 12 is rotated at high speed in a clockwise direction, as indicated by the arrow in Figure 1, and effects a stock removal from the work in the machine. The regulating wheel 11, which rotates at a relatively slow speed in the direction of the arrow in Figure 1, controls the rate of rotation of the work in the machine. Thus, in operation, the parallel opposed faces of the wheels travel in opposite directions and form a grinding throat therebetween in which the work is placed.

Referring now to Figures 1, 2, and 3, an attachment, generally indicated at 21, is provided for supporting and acting upon the work as it passes through the grinding throat formed between the regulating and grinding wheels. In general, this attachment includes a framework supporting a work rest blade generally indicated at 22 (Figures 2, 4, and 6), a reciprocating shuttle plate generally indicated at 23 (Figures 2, 4, and 5) which moves transversely of the faces of the wheels, and driving mechanism for the shuttle plate generally indicated at 24. The work is fed into the grinding throat adjacent the left-hand edge of the grinding wheel, as viewed in Figure 2, and is moved across the grinding throat by the shuttle plate from left to right, during which time the work is acted upon by the shuttle plate, grinding wheel, and regulating wheel, all as will be fully described hereinafter.

The framework of the attachment includes a

bed plate generally indicated at 25 (Figures 2 and 4), a pair of vertical supports 27 and 28 (Figure 2), and a transverse plate 29. Bed plate 25 extends transversely across the machine in alignment with the grinding throat between the grinding and regulating wheels (Figures 1 and 2) and is secured to slide 14 (Figure 2) by screws 26. Screws 26 extend through slots in bed plate 25 extending longitudinally of the machine and thread into carriage 14. Thus, the attachment may be adjusted toward and from the regulating wheel. The vertical supports 27 and 28 extend upwardly from and are secured to bed plate 25 adjacent the ends thereof and support transverse plate 29 above and parallel to bed plate 25. The rear face of bed plate 25, as viewed in Figures 2 and 4, has a cut-out portion 30 within which work rest blade 22 is positioned. This blade is secured in a vertical position to the bed plate by a series of bolts 31 which extend through vertical slots, such as slot 32 (Figures 3 and 4), in the work rest blade, pass through holes in the bed plate of substantially the same diameter as the shank of the bolts, and thread into nuts 33 (Figures 2 and 4). The slots are also of substantially greater width than the diameter of the shank of the bolts 31 (Figure 3), thus permitting adjustment of the work rest blade both vertically and longitudinally with respect to the bed plate 25. Elevating screws, such as screw 34 (Figures 3 and 4), are provided to permit accurate vertical adjustment of the work rest blade to be made, and longitudinal adjusting screws, such as screw 35 (Figures 3 and 4), are provided for making accurate longitudinal adjustments of the work rest blade with respect to the bed plate. Longitudinal screw 35 (Figure 3) acts against a boss 36 formed on a vertical support 37 secured to the rear face of bed plate 25. Thus, the work rest blade is accurately adjustable both vertically and longitudinally and, when so adjusted, is clamped in place by bolts 31.

The upper portion 38 of the work rest blade 22 (Figures 4 and 6) is tapered to conform to the shape of the grinding wheels, and the upper edge 39 of the blade 22 extends transversely across the faces of the grinding and regulating wheels (Figure 2) parallel to the grinding throat formed therebetween. The upper edge 39 (Figures 4 and 6) of the work rest blade is beveled toward the regulating wheel 11, thus insuring rotation of the balls by the regulating wheel. The beveled edge 39 of the work rest blade extends a substantial distance to the left of the grinding and regulating wheels (Figures 2 and 3) which are of substantially the same width.

Shuttle plate 23 is mounted on four rollers 40, 41, 42, and 43 which are positioned in the same plane as work rest blade 22 (Figures 4 and 5). As the mounting of rollers 42 and 43 upon the bed plate is substantialy similar, detailed description of these rollers will be limited to the mounting of roller 42. As best shown in Figures 3 and 5, a bracket 44 is secured by bolts 45 to the rear face of bed plate 25. Bolts 45 extend through vertical slots 46 in bracket 44 and thread into bed plate 25. Thus, the position of bracket 44 with respect to bed plate 25 may be adjusted vertically. A shaft 47 (Figure 5) is mounted in the upper portion of bracket 44, and roller 42 is revolubly mounted upon this shaft. Thus, rollers 42 and 43 may be adjusted verticaly with respect to the bed plate (Figure 2) permitting vertical adjustment of the shuttle plate 23 with respect to the work rest blade 22.

As the mounting of rollers 40 and 41 (Figure 2) upon vertical supports 27 and 28 is substantially similar, detailed description of the mounting of these rollers will be limited to the mounting of roller 40. Referring to Figure 3, an arm 48 is pivotally mounted at 49 on vertical support 27. A shaft 50 (Figures 3 and 5) is mounted in the right-hand end of arm 48, as viewed in Figure 3, and is held thereby by a bolt 51. Roller 40 is revolubly mounted on shaft 50 above roller 42. A projection 52 (Figure 3) extends outwardly from the end of arm 48 and is connected by a spring 53 to a bolt 54. Bolt 54 extends through and is adjustably connected to a bracket 55 (Figures 3 and 5) secured to the rear face of bed plate 25. Spring 53 resiliently urges arm 48 downwardly and, by adjusting nuts 56, the tension on spring 53, and thus the force acting downwardly upon arm 48, may be increased or decreased.

Referring to Figure 3, an elevating screw 57 threads through a boss 58 on vertical support 27 and acts upon a lug 59 formed on the rear face of arm 48. Arm 60 (Figure 2) of roller 41 is acted upon by an elevating screw similar to screw 57, and thus these rollers may be moved upwardly by their respective elevating screws to permit removal of the shuttle plate. Thus rollers 40 and 41 are resiliently urged downwardly against the upper edges of the shuttle plate and act as effective guides during movement of the blade, and the shuttle plate may be conveniently removed from the attachment.

As is best shown in Figures 2 and 5, the upper and lower edges 61, 62, 63, and 64 of shuttle plate 23 adjacent the ends thereof are preferably beveled (Figure 5) to fit the grooves in rollers 40, 41, 42, and 43, respectively. Thus, shuttle plate 23 is mounted on the rollers for movement transversely of the grinding throat between the grinding and regulating wheels and is maintained by the rollers in a vertical position above the work rest blade 22. Furthermore, the shuttle plate may be vertically adjusted by adjusting the brackets upon which rollers 42 and 43 are mounted and an efficient mounting of the shuttle plate is achieved through the action of the resilient springs urging rollers 40 and 41 downwardly.

As best shown in Figures 2 and 3, the lower edge of the shuttle plate 23 has a cut-out portion 65 therein into which the beveled edge 39 of the work rest blade extends. Referring to Figures 2 and 6, retainer blades 66, 67, and 68 are mounted on the lower edge of the cut-out portion of shuttle plate 23 and are held in position thereon by a clamping plate 69 and bolts 70. The lower edges of blades 66, 67, and 68 are positioned parallel and in alignment with the beveled edge 39 of the work rest blade. A small wire 71 (Figure 6) is positioned between the upper edges of the retainer blades and shuttle plate 23 and may be changed to a wire of different size for accurately locating the retainer blades vertically with respect to the balls. This permits the blades to be adjusted for balls of different sizes. The retainer blades are preferably positioned just far enough above the balls so that the blades do not touch the balls but will prevent them from jumping out of, or piling up in, the grinding throat during operation of the shuttle plate.

The balls 72 are reciprocated in the grinding throat by actuating pins 73 (Figure 3) and 74 (Figure 2). Actuating pin 73 is mounted in a support 75 which is secured to shuttle plate 23

by screws 76. This pin, which is in alignment with the centers of the balls in the grinding throat, is threaded through a downwardly projecting portion 75a of support 75, and by turning its head 78, which is positioned in a cut-out portion 79 of shuttle plate 23, the actuating end 73a of pin 73 may be adjusted with respect to the shuttle plate.

Pin 74 (Figure 2), which extends through a hole 80 in the lower part of the right-hand portion of the shuttle plate, threads through an end plate 81. This pin is also in alignment with the centers of the balls in the grinding throat, and its position may be adjusted by turning its head 82. Pins 73 and 74 serve to move the line of balls positioned along the edge 39 of the work rest blade to the right and left, as viewed in Figure 2, as shuttle plate 23 reciprocates, all as will be fully described hereinafter.

The portion of the beveled edge 39 of the work rest blade, which extends to the left of the grinding and regulating wheels as viewed in Figures 2 and 3, is enclosed by a pair of plates 83 and 84 (Figures 2 and 4) secured to the work rest blade 22 by bolts 86 and 87; the plates extend above the beveled edge 39 of blade 22 (Figure 4) thus to enclose the left-hand end of the train of balls, as viewed in Figure 2.

As best shown in Figures 2, 3, and 4, a work feeding tube 88 extends upwardly above the framework of the attachment and is mounted upon transverse plate 29 in any suitable manner. The lower end of the tube is aligned with a passageway 89 extending through a block 90. Block 90, which extends downwardly into a cut away portion of shuttle plate 23, is mounted by screws 225 (Figure 4) on a vertical support 37 (Figure 3) connected to bed plate 25. As is best shown in Figure 3, bolts 37a and 37b secure vertical support 37 to the rear face of bed plate 25 and extend through horizontal slots 200 and 201 in vertical support 37. Thus, the position of vertical support 37 and block 90 may be adjusted longitudinally with respect to bed plate 25 and shuttle plate 23.

The lower portion of block 90 has a channel 91 (Figures 3 and 11) therein which extends lengthwise across the block. This channel is closed to the left of passageway 89, as viewed in Figure 3, by a block 93 which is secured to block 90 by screw 94. The right-hand end of block 93 with the side walls of channel 91 forms a continuation of the work feeding passageway 89 in block 90. A cut-off blade 95 (Figures 3 and 11) is slidably mounted for longitudinal movement with respect to block 90 in the right-hand section of channel 91, as viewed in Figure 3. This blade has a pin 96 (Figures 2 and 3) which extends outwardly through an elongated slot 97 (Figure 2) in the side wall of channel 91. This pin is connected to a second pin 98 set in block 90 by a spring 99 which acts through pin 96 to resiliently urge the cut-off blade 95 (Figure 3) to the left, as viewed in this figure. The cut-off blade 95 is also provided with a threaded extension 100 thereon upon which a stop member 101 is mounted for purposes to be disclosed more fully hereinafter.

Immediately below block 90 a feed plate, generally indicated at 102, is mounted in a cut-out portion of shuttle plate 23. The upper surface of this plate retains cut-off blade 95 within channel 91 (Figures 2 and 3), and its right-hand end 102a, as viewed in Figure 3, coacts with stop member 101 to actuate the cut-off blade. As pointed out hereinabove, shuttle plate 23 moves with a reciprocating action, and when the shuttle plate is positioned at the right-hand end of its stroke, as viewed in Figures 2 and 3, the string of balls in tube 88 and block 90 rests on the upper flat surface 103 of plate 102. To the right of surface 103 a passageway 104 slants downwardly through feed plate 102 and connects with a passageway 105 extending through shuttle plate 23 and support 75 (Figures 3 and 11).

In operation, as shuttle plate 23 moves to the left as viewed in Figure 3, movement of feed plate 102 permits spring 99 (Figure 2) to move the cut-off blade 95 in the same direction. The V-shaped nose 106 of the blade extends between the two lower balls in the string of balls resting on surface 103. This separates the lowermost ball from the string and retains the other balls above the blade in block 90 and tube 88 as the shuttle plate continues its stroke to the left, as viewed in Figures 2 and 3. During this movement of the shuttle plate, the slanting surface of passageway 104 moves beneath the bottom ball causing it to move down passageway 104 and enter passageway 105 in the shuttle plate. An adjustable stop 107 is provided threading into the right-hand end of block 90 which limits the movement of the cut-off blade to the left, as viewed in Figure 3.

When the shuttle plate moves to the right, as viewed in Figure 3, and is approaching the end of its stroke in that direction, the end portion 102a of feed plate 102 strikes stop member 101 and thus carries the nose of cut-off blade 95 from the path of the balls feeding through block 90. The balls accordingly move downwardly, the lowermost ball striking the flat surface 103 of feed plate 102. On the return movement of the shuttle plate, the lowermost ball is again cut off from the string and fed into the grinding throat.

As is best shown in Figures 2 and 9, the end of actuating pin 74 moves a slightly greater distance than the width of one ball beyond the beveled edge 39 of the work rest blade 22 when the shuttle plate 23 is at the end of its stroke to the right, as viewed in Figure 2. The ball which moves over the end of edge 39 falls downwardly between plates 108 and 109 (Figures 9 and 10) and enters a passageway 110 (Figure 2) in block 111 secured to the rear face of bed plate 25. The balls passing from the end of passageway 110 drop into a trough 112 by which they leave the machine. A resilient finger 113 (Figures 9 and 10) is mounted on bolt 114, and its upper end is positioned immediately above the end of beveled edge 39 (Figure 9) of the work rest blade. This finger engages the upper portions of the balls as they reach the end of the grinding throat and prevents more than one ball from leaving the grinding throat each time the shuttle moves to the right, as viewed in Figure 3, all as will be described hereinafter.

In operation, each time the shuttle plate moves to the right, as viewed in Figure 2, the balls in the grinding throat are moved by actuating pin 73 against the end of actuating pin 74, and at the end of the stroke in this direction, the ball which has been pressed beyond finger 113 falls off the edge of the work rest blade and leaves the machine, finger 113 holding the remainder of the balls on beveled edge 39. At this time, the end 73a of actuating pin 73 is positioned adjacent the left edge of passageway 105 as viewed in Figure 3.

As the plate moves to the left as viewed in Figure 3, there is a lost motion period before the end of actuating pin 74 strikes the ball retained

by finger 113 in the grinding throat, and as pin 73 is moving to the right during this lost motion period, a space is provided at the left-hand end of the train of balls on the edge of the work rest blade. During this same movement a ball is cut off from the string of balls in block 90 and falls down into passageway 105 into this space. Thus, as the shuttle plate moves to the right, as viewed in Figure 2, a ball leaves the grinding throat, and as the shuttle moves to the left, a ball is added to the right-hand end of the train of balls passing therethrough. An opening 116 (Figures 3 and 11) is provided in the rear of passageway 105. This opening permits balls to escape from the shuttle plate, should they start to pile up therein due to failure of the feeding process.

The hydraulic mechanism 24 (Figure 2) is mounted on the framework of the attachment by supports 221 and 222 which are secured to the bed plate 25 and transverse plate 29, respectively. Shuttle plate 23 (Figure 3) is driven by a piston rod 121 which is connected to piston 120 of hydraulic mechanism 24. This rod is connected to the shuttle plate by a swivel joint 122 and is connected to piston 120 by nut 123. The reciprocating movement of piston 120 in its cylinder 124 is controlled by the hydraulic control system diagrammatically shown in Figure 8. A pilot valve, generally indicated at 127, which controls a reversing valve, generally indicated at 128 (Figure 3), which in turn controls piston 120, is mechanically operated by shuttle plate 23.

Referring to Figure 7, a shifter rod 129 extends through a hole in vertical support 27. This rod is prevented from rotating within the support by a set screw 130 and has adjustable shoulders 131 and 132 secured to its opposite ends. It will be noted that the end of set screw 130 engages a slot in shifter rod 129, thus permitting movement of the shifter rod transversely of vertical support 27. Shoulder 131 engages a slot 133 in the end of the stem 134 of pilot valve 127 and shoulder 132 extends forwardly from rod 129 and is positioned in the path of the end plate 126 of shuttle plate 23. Thus, as the shuttle plate moves to the right, as viewed in Figures 3 and 7, end plate 126 strikes shoulder 132 and moves the pilot valve stem 134 to the right through shifter rod 129 and shoulder 131, thus changing the setting of the pilot valve. When the shuttle plate moves in the opposite direction and approaches the end of its stroke, an adjustable stop 125 on end plate 126 strikes the end of the pilot valve stem 134 and moves it to the left to reverse the position of the pilot valve. Accordingly, movement of the shuttle plate to the left or right, as viewed in Figures 2 and 3, controls the movement of the pilot valve, and as the shuttle plate approaches the end of its stroke in either direction, the pilot valve is shifted to reverse the action.

Referring now to Figure 1, a casing, generally indicated at 135, is shown which contains a pump, a relief control valve, and a sump. From this casing, pressure and sump conduits 136 and 137, respectively, enter a stop control valve 138. A pair of flexible conduits 139 and 140 connect stop control valve 138 with hydraulic control mechanism 24.

As best shown in Figure 8, a pump 141 pumps the hydraulic fluid from sump 142 to stop control valve 138 through conduit 136. In conduit 136 between pump 141 and stop control valve 138 a relief valve 143 is provided to insure a constant pressure. When stop control valve 138 is in its "on" position, as indicated by the dotted lines 144, conduit 136 is connected to pressure conduit 139. This conduit enters the center portion of both pilot valve 127 and reversing valve 128. Sump conduit 137, which connects stop control valve 138 to the sump, at this time is connected to sump conduit 140 which in turn is connected to ports 145 and 146 of pilot valve 127 and ports 147 and 148 of reversing valve 128. A pair of conduits 149 and 150 connect reversing valve 128 to the cylinder within which piston 120 is positioned, and a pair of conduits 151 and 152 connect pilot valve 127 to reversing valve 128. In conduits 151 and 152 are check valves 153 and 154 which permit the hydraulic fluid to flow from the pilot valve 127 to the reversing valve 128 but prevent flow in the opposite direction. These check valves are by-passed by choke coils 155 and 156 for purposes to be disclosed more fully hereinafter.

In operation, when piston 120 has moved shuttle plate 23 to the right, as viewed in Figure 2, its end plate 126 (Figure 7) moves the pilot valve stem 134 to the right to the position shown in Figure 8. It will be noted that the pilot valve 127 has an enlarged central spool 157 which provides a pressure differential and makes the valve self-actuating after the spool passes the center pressure port 158.

After the pilot valve has been moved to the right into the position shown in Figure 8 by end plate 126 (Figure 7), pressure from conduit 139 entering the pilot valve through port 158 leaves this valve through conduit 151, passes check valve 153, and enters port 170 of the reversing valve. The pressure fluid entering this port moves the reversing valve to the right to the position shown in Figure 8. Hammering of this valve against the end of the cylinder housing is prevented by choke coil 156 which delays the flow of the pressure fluid from the opposite end of the cylinder. The fluid leaving this valve passes through conduit 152 to pilot valve 127 and thence to the sump through port 146 and sump conduit 140.

When the reversing valve is in the position shown in Figure 8, pressure fluid entering reversing valve 128 through port 160 passes out through port 178 of the reversing valve into conduit 149. As this conduit enters the right-hand end of the cylinder enclosing piston 120, piston 120 and shuttle plate 23 move to the left, as viewed in Figure 2.

As the shuttle plate approaches the end of its stroke to the left, as viewed in Figure 2, adjustable stop 125 (Figures 3 and 7) engages the end of pilot valve stem 134. This moves the spool 157 (Figure 8) of the pilot valve to the left of pressure port 158. This places pressure port 158 in communication with conduit 152 which causes the pressure fluid to move the reversing valve 128 to the left, as viewed in Figure 8. This places pressure port 160 in communication with conduit 150 which causes the pressure fluid to enter the right-hand end of piston cylinder 124, thus causing piston 120 to move the shuttle plate to the right, as viewed in Figure 2.

Thus, shuttle plate 23 is moved with a reciprocating action by the hydraulic mechanism generally indicated at 24, and this movement is directly controlled by the shuttle plate through the tripping mechanism shown in Figure 7. The rate of reciprocation of the shuttle plate may be controlled by regulating the pressure of the fluid in the hydraulic system through pressure relief valve

143 (Figure 8). It has been found that two hundred cycles of reciprocation per minute of the shuttle plate 23 are desirable in practice. When an attachment of this type is used, it has been found that a series of machines may be used to grind balls from a rough state down to a finished product, all according to the type of grinding being done by the machine.

As is best shown in Figure 7, the length of the stroke of the shuttle plate may be adjusted by adjusting the position of shoulders 131 and 132 on shifter rod 129. Preferably the advancing movement of the balls is equivalent to approximately the circumference of a ball during the movement of the shuttle plate to the right, as viewed in Figure 2. This gives each ball one complete revolution during the movement of the shuttle plate in this direction. As a ball leaves the train of balls supported by the work rest blade at the end of this stroke, and as there is a lost motion period between the time the end of actuating pin 74 engages the ball at the right-hand edge of the work rest blade on the return stroke of the shuttle, the return movement of the balls is equal to approximately two-thirds of their circumference, although the strokes of the shuttle plate in either direction are equal. Accordingly, the train of balls advances approximately the diameter of one ball for each reciprocation of the shuttle plate. The actual movement of the shuttle plate is preferably slightly greater than the amounts given hereinabove because sufficient lost motion must be introduced to compensate for eccentricities in the balls in the train on the work rest blade.

In operation, balls are fed into the feeding tube 88 (Figures 2 and 3) and are fed into the train of balls on the work rest blade one at a time as described hereinabove. This is controlled by the reciprocation of the shuttle plate. During each reciprocation a ball is ejected from the train as described hereinabove. As the balls pass through the grinding throat, the regulating wheel 11 (Figure 1) rotates the balls, and the grinding wheel removes stock from them as irregularities or excess metal of the balls are presented. In the removal of stock the grinding wheel tends at any given instant to cut along the line of a great circle, but the simultaneous rotation about another axis continually changes the direction of the great circle along which the cutting takes place. Thus the total effect on the balls as they are passed through the throat rotated by the shuttle results in a true sphere whose surface is completely defined by the continuous cutting along lines at a constant radius from the center of the sphere. Metal is never removed below the exact diameter of the sphere, for that diameter is determined by the distance from the grinding surface to the coacting point on the regulating wheel. In like manner, the metal in no direction and at no point exceeds this precise diameter, for such metal is ground away by the cutting action which has been brought to bear upon every point on the surface of the sphere during the travel of the balls through the throat of the machine.

It will thus be seen that a thoroughly efficient and practical method and apparatus for grinding balls on a centerless grinding machine has been disclosed. The apparatus is in the form of an attachment which may be installed on standard centerless grinding machines having flat wheels. This results in a material saving of abrasive material, more efficient operation, and balls which are accurately ground.

Thus, the several objects mentioned hereinabove, as well as many others, are successfully and practically accomplished by the method and apparatus disclosed hereinabove.

As many possible embodiments may be made of the mechanical features of the above invention, and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinabove set forth, or shown in the accompanying drawings, is to be interpreted as illustrative and not in a limiting sense.

We claim:

1. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat, work rest means for supporting a train of balls in said grinding throat, and means for moving said balls with a reciprocating movement transverse to the faces of said wheels as said balls move through said grinding throat.

2. In apparatus of the nature described, in combination, a grinding wheel, a regulating wheel for rotating a train of balls in the grinding throat formed between the grinding and regulating wheels in a direction toward the grinding wheel, means for supporting said balls in said grinding throat, and reciprocating shuttle means for rotating said balls in directions transverse to the direction of rotation of said wheels as said balls pass through said grinding throat.

3. In apparatus of the nature described, in combination, a grinding wheel, a regulating wheel for rotating a train of balls in the grinding throat formed between the grinding and regulating wheels in a direction toward the grinding wheel, means for supporting said balls in said grinding throat in substantially a straight line with respect to each other, means other than said wheels for causing the rotation of said balls in a direction transverse to the direction of rotation of said wheels during the grinding of said balls in said grinding throat, and means to prevent said balls from moving upwardly out of said grinding throat as they move therethrough.

4. In apparatus of the nature described, in combination, a grinding wheel, a regulating wheel for rotating a train of balls in the grinding throat formed between the grinding and regulating wheels in a direction toward the grinding wheel, means for supporting said balls in said grinding throat, reciprocating actuating means for rotating said balls in directions transverse to the direction of rotation of said wheels as said balls pass through said grinding throat, and means to prevent said balls from moving upwardly out of said grinding throat as they move therethrough.

5. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, said grinding and regulating wheels having straight operative faces, work rest means having a substantially straight work supporting edge, means for feeding balls onto said work rest means adjacent one edge of said grinding wheel, means for removing balls from said work rest means adjacent the other edge of said grinding wheel, and actuating means for moving said balls through said grinding throat and causing them to rotate transversely to the direction of rotation imparted to said balls by said regulating wheel during the actual grinding of said balls in said throat.

6. In apparatus of the nature described, in

combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means, means for feeding balls onto said work rest means adjacent one edge of said grinding wheel, means for removing balls from said work rest means adjacent the other edge of said grinding wheel, actuating means for moving said balls through said grinding throat and for causing them to rotate transversely to the direction of rotation of said wheels, and retainer means positioned above said work rest means for preventing the balls from moving upwardly out of the grinding throat.

7. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means, means for feeding balls onto said work rest means adjacent one edge of said grinding wheel, means for removing balls from said work rest means adjacent the other edge of said grinding wheel, actuating means for moving said balls through said grinding throat and for causing them to rotate transversely to the direction of rotation of said wheels, and retainer means positioned above said work rest means for preventing the balls from moving upwardly out of the grinding throat, said retainer means and said work rest means being adjustable toward and from each other.

8. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means, means for feeding balls onto said work rest means adjacent one edge of said grinding wheel, means for removing balls from said work rest means adjacent the other edge of said grinding wheel, reciprocating actuating means for causing said balls to rotate in directions to the right and left of the direction of rotation imparted to said balls by said regulating wheel, and means for causing the movement of said balls through said grinding throat.

9. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, a work rest blade positioned transversely of the face of said grinding wheel and adapted to support a train of balls in said grinding throat, a reciprocating shuttle adapted to move transversely of the face of said grinding and regulating wheels, and means on said shuttle for causing said balls to rotate in directions transverse to the direction of rotation of said wheels.

10. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel having a grinding throat formed therebetween, means for supporting a train of balls in said grinding throat, a shuttle plate, means for moving said shuttle plate with a reciprocating action, and means on said shuttle plate for acting against the ends of the train of balls positioned in said grinding throat, whereby said balls are rotated in both directions by said actuating means transverse to the direction of rotation of said wheels.

11. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel having a grinding throat formed therebetween, means for supporting a train of balls in said grinding throat, a shuttle plate, means for moving said shuttle plate with a reciprocating action, means on said shuttle plate for acting against the ends of the train of balls positioned in said grinding throat, whereby said balls are rotated in both directions by said actuating means transverse to the direction of rotation of said wheels, and retaining means positioned above said train of balls to prevent movement of said balls upwardly out of the grinding throat.

12. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel having a grinding throat formed therebetween, means for supporting a train of balls in said grinding throat, a shuttle plate, means for moving said shuttle plate with a reciprocating action, means on said shuttle plate for acting against the ends of the train of balls positioned in said grinding throat, whereby said balls are rotated in both directions by said actuating means transverse to the direction of rotation of said wheels, and retaining means positioned above said train of balls to prevent movement of said balls upwardly out of the grinding throat, said work supporting means and said retaining means being adjustable toward and from each other, whereby the position of said balls in said grinding throat may be varied to accommodate balls of different sizes.

13. In apparatus of the nature described, in combination, a grinding wheel, a regulating wheel for rotating a ball positioned in the grinding throat formed between the grinding and regulating wheels, said ball being rotated by said regulating wheel in a direction toward said grinding wheel, and reciprocating shuttle means acting upon said ball to rotate said ball in directions transverse to the direction of rotation of said wheels.

14. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means for supporting balls in said grinding throat, means for feeding said balls into said grinding throat, means to permit removal of said balls from said grinding throat, and reciprocating means acting upon said balls in said grinding throat to move said balls in directions transverse to the faces of said wheels.

15. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means for supporting a train of balls in said grinding throat, means for feeding said balls into said grinding throat, means to permit removal of said balls from said grinding throat, and oscillating means acting upon the ends of said train of balls in said grinding throat to move said train of balls with a reciprocating movement transverse to the faces of said wheels.

16. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means for supporting a train of balls in said grinding throat, reciprocating means, and means on said reciprocating means acting on the ends of said train of balls on said work rest means to oscillate said train of balls transversely with respect to the faces of said wheels.

17. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means for supporting a train of balls in said grinding throat, reciprocating means, means on said reciprocating means acting on the ends of said train of balls on said work rest means to oscillate said train of balls transversely with respect to the faces of said wheels, and means to prevent said balls from moving upwardly out of said grinding throat during the oscillation of said train of balls.

18. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means for supporting a train of balls in said grinding throat, reciprocating shuttle means for moving said train of balls in directions transverse to the faces of said wheels, hydraulic means for driving said shuttle means, and tripping mechanism operated by said shuttle means for controlling the direction of movement and length of stroke of said hydraulic driving means.

19. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means for supporting a train of balls in said grinding throat, reciprocating shuttle means for moving said train of balls in directions transverse to the faces of said wheels, means controlled by movement of said shuttle means for feeding balls to said train of balls, and means controlled by said shuttle means for removing balls from said train of balls.

20. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat therebetween, work rest means for supporting a train of balls in said grinding throat, reciprocating shuttle means for moving said train of balls in directions transverse to the faces of said wheels, means controlled by movement of said shuttle means for feeding balls to said train of balls, means controlled by said shuttle means for removing balls from said train of balls, and means on said shuttle means for retaining said balls in said grinding throat.

21. The herein described art which includes the steps of, supporting a plurality of balls, grinding said balls in the general direction of the means by which said balls are supported, applying a rotating force to said balls in substantially the opposite direction on sides substantially opposite to the sides being ground, and moving said balls during said grinding with a reciprocating action transverse to the direction of said grinding.

22. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel having a grinding throat therebetween, said grinding wheel and said regulating wheel having substantially straight operative faces, means for supporting a train of balls in said grinding throat in a substantially straight line with respect to each other, and means for causing rotation of said balls in a direction transverse to the direction of rotation of said wheels as said balls are being ground in said grinding throat.

23. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel having a grinding throat therebetween, said grinding wheel and said regulating wheel having substantially straight operative faces, means for supporting a train of balls in said grinding throat in a substantially straight line with respect to each other, and means for causing rotation of said balls in directions transverse to the direction of rotation of said wheels as said balls are being ground in said grinding throat.

24. In apparatus of the nature described, in combination, a grinding wheel and a regulating wheel forming a grinding throat, said grinding wheel and regulating wheel being adjustable toward and from each other, work rest means for supporting a train of balls in said grinding throat, said work rest means being adjustable upwardly and downwardly in said grinding throat, and means for moving said balls with a reciprocating movement transverse to the faces of said wheels as said balls pass through said grinding throat.

25. The herein described art which includes the steps of, supporting a train of balls in a grinding throat formed between a grinding wheel and a regulating wheel, grinding said balls in the general direction of the means by which said balls are supported, said regulating wheel rotating said balls to move their surfaces adjacent the grinding wheel in substantially the same direction as the adjacent surface of the grinding wheel, and moving said train of balls during grinding in directions transverse to the direction of rotation of said wheels with a reciprocating action and with an excess of forward movement to successively move said balls through and out of said grinding throat.

26. The herein described art which includes the steps of, supporting a plurality of balls in a grinding throat formed between a grinding wheel and a regulating wheel, grinding said balls in the general direction of the means by which said balls are supported, said regulating wheel rotating said balls to move their surfaces adjacent the grinding wheel in substantially the same direction as the adjacent surface of the grinding wheel, feeding balls during grinding to said grinding throat, removing balls during grinding from said grinding throat, and during grinding moving said balls with a reciprocating action transverse to the faces of said wheels.

FREDERICK J. THELER.
GEORGE W. BINNS.
JACOB DECKER.