March 12, 1957 A. F. TOWNSEND ET AL 2,784,534

INTERNAL GRINDING MACHINES

Filed July 20, 1953 5 Sheets-Sheet 1

FIG. 1

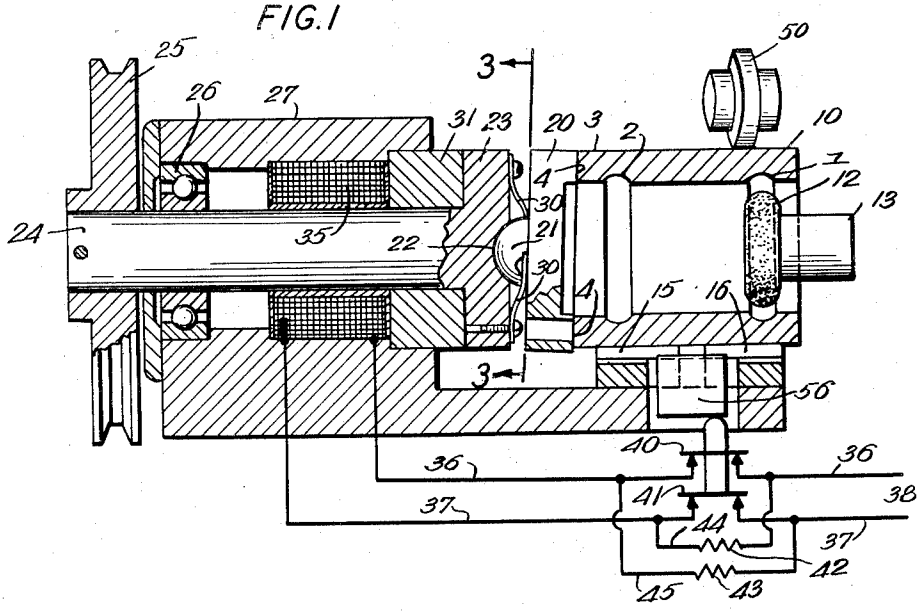
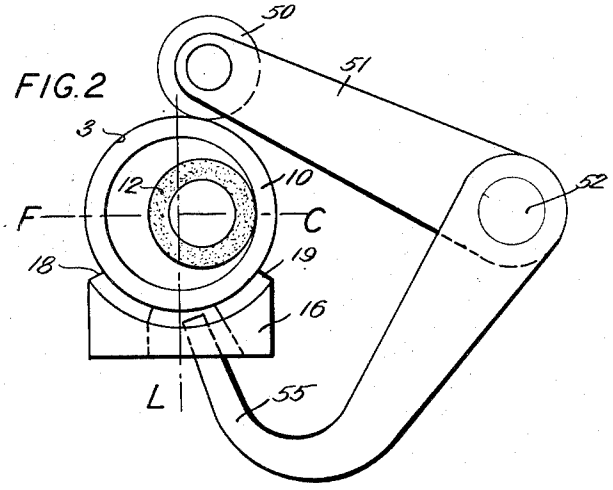


FIG. 2



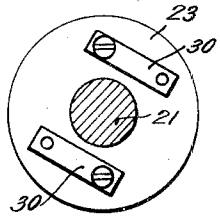


FIG. 3

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March 12, 1957 A. F. TOWNSEND ET AL 2,784,534

INTERNAL GRINDING MACHINES

Filed July 20, 1953 5 Sheets-Sheet 2

FIG. 4

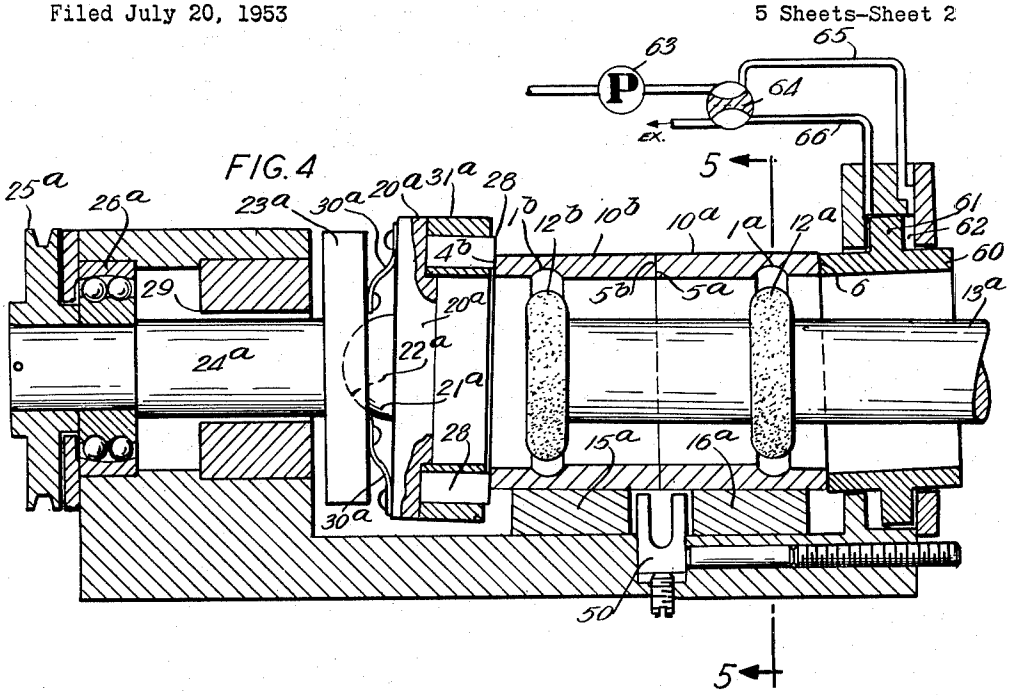
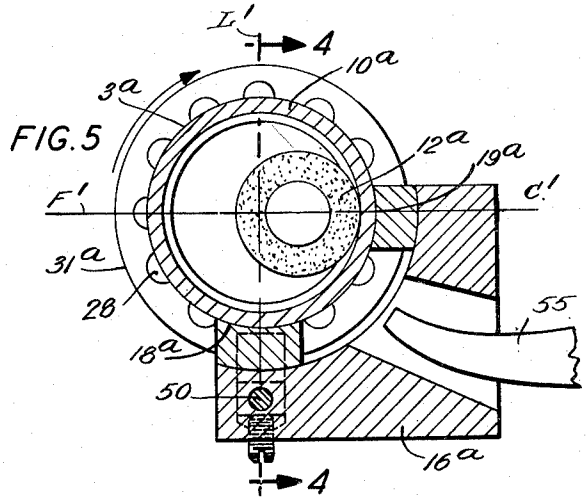


FIG. 5



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INTERNAL GRINDING MACHINES

Filed July 20, 1953 5 Sheets-Sheet 3

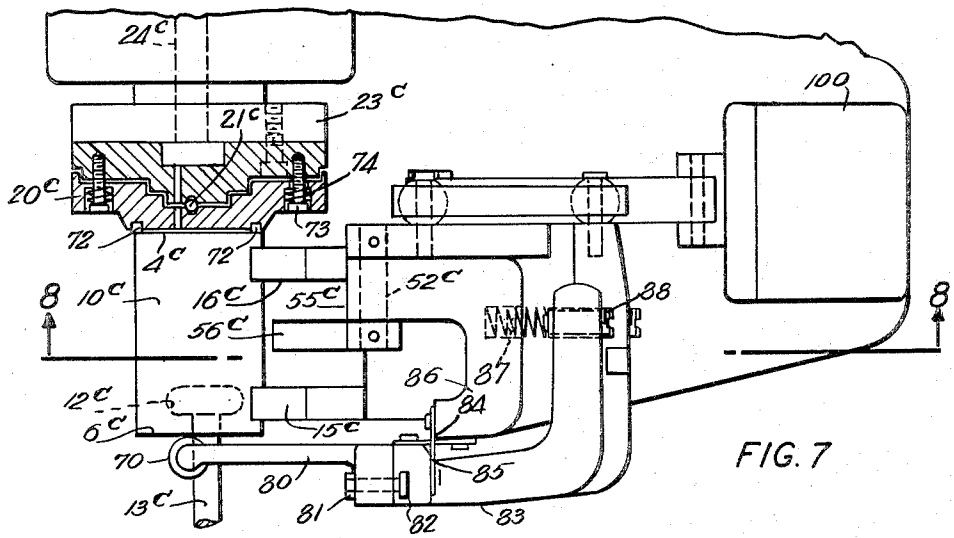
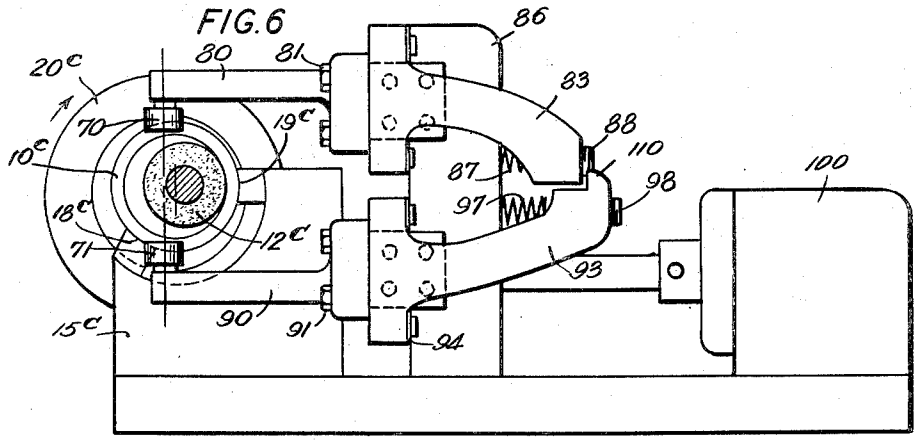


FIG. 7

FIG. 6



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INTERNAL GRINDING MACHINES

Filed July 20, 1953 5 Sheets-Sheet 4

FIG.8

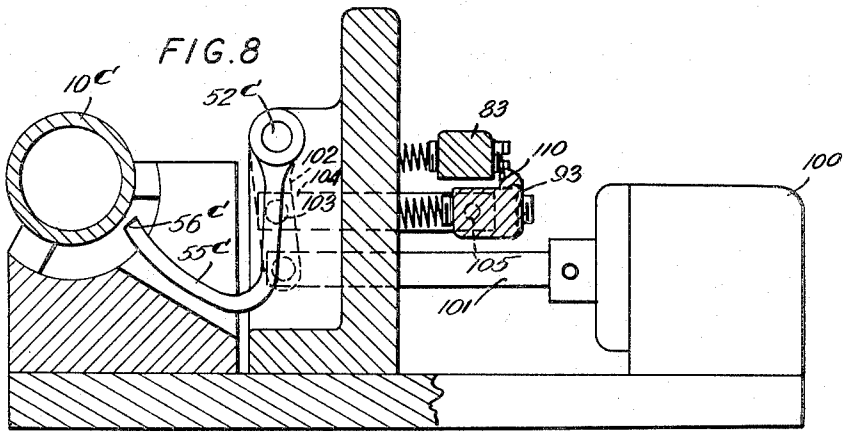
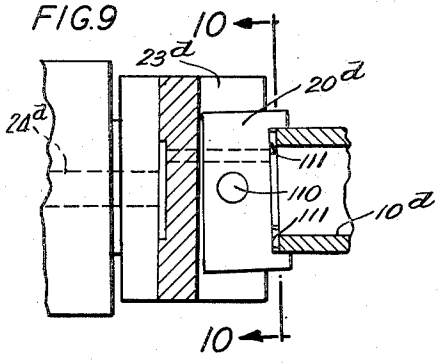


FIG.9



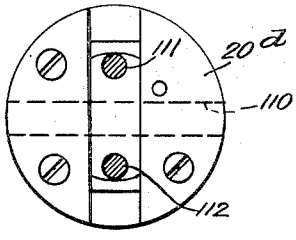


FIG.10

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INTERNAL GRINDING MACHINES

Filed July 20, 1953 5 Sheets-Sheet 5

FIG.11

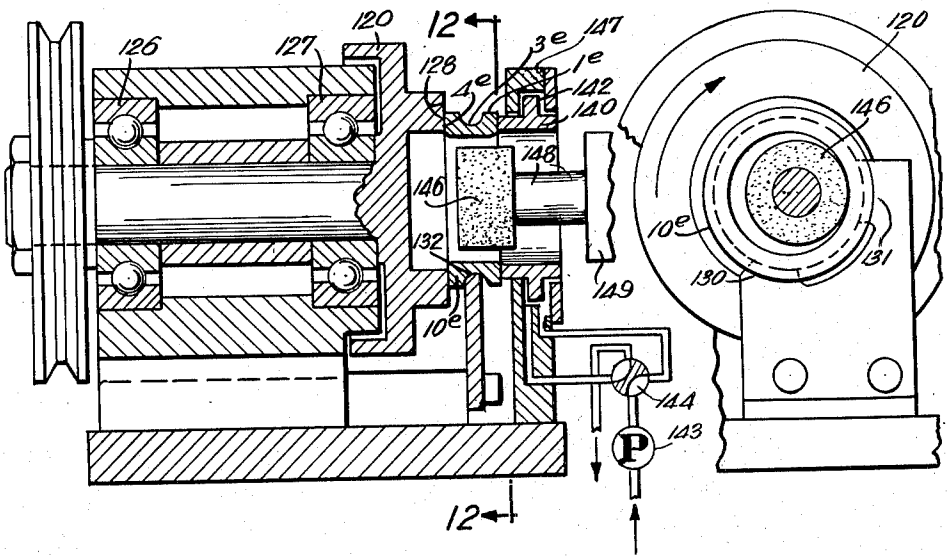


FIG.12

FIG.14

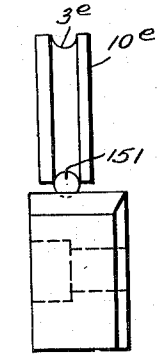
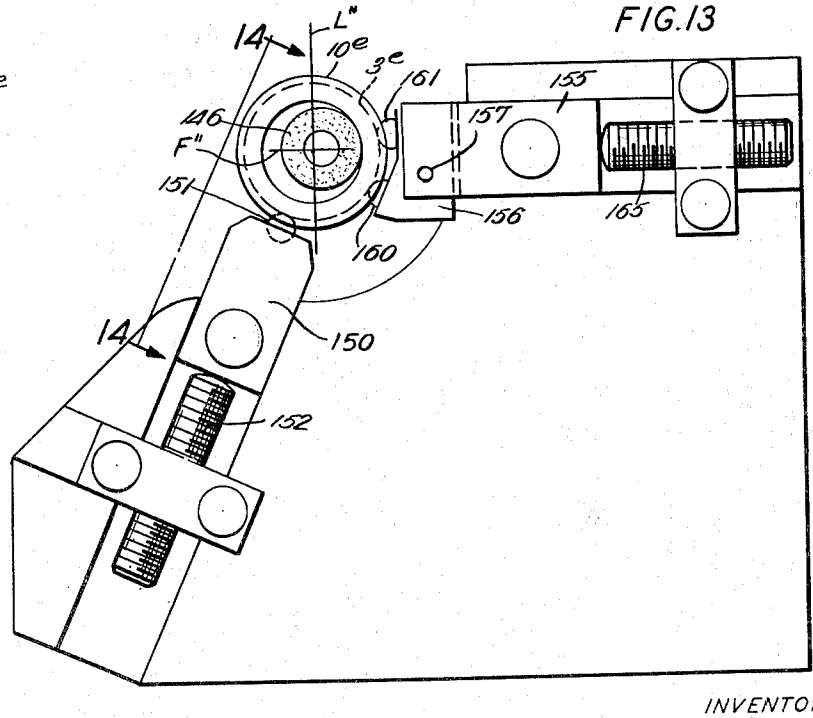


FIG.13



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United States Patent Office 2,784,534 Patented Mar. 12, 1957

2,784,534

INTERNAL GRINDING MACHINES

Almon F. Townsend and Harold L. Blood, Worcester, Mass., assignors, by mesne assignments, to The Heald Machine Company, a corporation of Delaware

Application July 20, 1953, Serial No. 368,912

23 Claims. (Cl. 51—103)

This invention relates to internal grinding machines of the centerless or chuckless type in which workpieces are guided by their preformed outer surfaces of revolution while being rotated and a rotating tool is applied to refine internal surfaces of revolution in the workpieces. More particularly, this comprises improvements for certain purposes in machines of this type disclosed in the Blood application, Serial No. 242,102, filed August 16, 1951, now Patent No. 2,646,652, dated July 28, 1953.

It is desirable to refine one or more inner surfaces of a round workpiece so that the finished inner surface has a predetermined concentric relation with an outer surface of revolution and in some cases without any particularly accurate relation with respect to the end faces of the workpiece. In fact, many workpieces have end faces which are out of square with respect to their axes of revolution and therefore such a workpiece cannot be supported with its end face against a back plate whose abutting face remains square to the axis of revolution of the workpiece. Nevertheless, in the supporting and rotating of a workpiece being finished, it is desirable to drive it and also to maintain its position in an endwise direction by contact of a member with one or more of its end faces while accurately maintaining its axis of rotation so that its internal surface may be finished with respect thereto, by supporting it in means in contact with its outer surface of revolution which eliminates inaccuracies due to irregularities in the outer surface portion and variations in outside diameter as between successive workpieces. It is also desirable to provide support means in contact with the said outer surface which is axially long enough, particularly for supporting long workpieces, i. e., having a length greater than the diameter, so that the workpiece rotates on a fixed accurately predetermined axis.

Accordingly this invention provides means for internally grinding work of such proportions that its axis of rotation may be fixed by fixed concave supports engaging the periphery, and its endwise location may be fixed accurately by a plate engaging a finished face of the work, even though the face is not quite at right angles to the periphery; also means for internally grinding annular work in which concentricity of the ground surface with the preformed periphery is more important than squareness of the ground surface with a face of the work, assuming the face is not perfectly square with the periphery; also improved means for controlling the speed of rotation of work subjected to heavy cuts, while keeping distortion of the work at a minimum.

These and other features and objectives will become apparent from the following description of the invention and from the drawings in which:

Fig. 1 is a longitudinal section through one embodiment of the invention.

Fig. 2 is an end view of Fig. 1.

Fig. 3 is a section taken along the lines 3—3 in Fig. 1.

Fig. 4 is a longitudinal section through another embodiment.

Fig. 5 is a section taken on the lines 5—5 of Fig. 4.

Fig. 6 is an end view of another embodiment looking along the axis of the workpiece.

Fig. 7 is a top plan view of the embodiment of Fig. 6.

Fig. 8 is a sectional view taken along the lines 8—8 of Fig. 7.

Fig. 9 is a partial longitudinal view of a still further embodiment.

Fig. 10 is an end view taken along the lines 10—10 of Fig. 9.

Fig. 11 is a longitudinal view partly in section of a further modification.

Fig. 12 is an end view of Fig. 11 taken on lines 12—12.

Fig. 13 is an end view of a modified work support.

Fig. 14 is a view of Fig. 13 on lines 14—14.

In the drawings, Fig. 1 shows a mechanism for grinding inner surfaces 1 and 2 of a long workpiece 10 including a grinding tool 12 on a spindle 13. The workpiece 10 is longer than its diameter and has an outer cylindrical surface 3 and an end surface 4 which is out of square with respect to the axis of the surface 3, this being exaggerated in the drawings for illustrative purposes. The workpiece is supported by work support means comprising a pair of fixed work supports 15 and 16, each having a pair of concave support surfaces 18 and 19 substantially conforming to the peripheral surface 3 of the workpiece and straddling a line L which is normal to the line F of feed of the wheel 12 into the work 10, thereby minimizing errors due to irregularities and variations in size of the outer surface 3 at the line of contact C between the wheel and the work, as seen in Fig. 2. Since the work is supported on the two supports 15 and 16, its axis of revolution is fixed. In order to maintain the workpiece in an endwise direction and to rotate it while it is being ground, a magnetic wobble plate 20 is provided to be rotated by a pulley 25 driven from any convenient power source not shown, and to wobble about its axis of rotation, i. e. rotate out of square to the axis, so that it can maintain a continuous all around abutting contact with the out-of-square end face 4 of the workpiece. For this purpose, a semi-spherical ball joint 21 integral with the wobble plate 20 is received in a corresponding semi-spherical concave bearing surface 22 in an enlarged end portion 23 of a magnetizable spindle 24 suitably supported by a bearing 26 in a work head 27 and on the outside end of which is mounted the pulley 25. The wobble plate 20 is also connected to be driven by the enlarged spindle end portion 23 by a pair of resilient reeds 30, also seen in Fig. 3. The reeds 30, being arranged between the spindle portion 23 and the plate 20 in a direction tangential to their rotation, are sufficiently rigid to transfer the torque and at the same time sufficiently flexible to allow the plate 20 to wobble freely within practical limits in any direction around the ball joint from a plane normal to the axis of the workpiece. Mounted on the spindle 24 behind its enlarged end portion 23 is a non-magnetic collar 31, which may be of bronze or similar material, which acts as a magnetic separator. Behind the separator 31 is a magnetic coil 35 surrounding the spindle 24 and energized by wires 36 and 37 connected to a suitable power source 38. A pair of switches 40 and 41 are connected in the lines 36 and 37 respectively and the wires 36 and 37 are cross connected around the switches 40 and 41 by resistances 42 and 43 and wires 44 and 45 respectively.

A resiliently loaded pressure roll 50 mounted on an arm 51 on a rock shaft 52 is urged downwardly by suitable spring means (not shown) to urge the workpiece, particularly its outer end, down against work supports 15 and 16. The roll 50 may also be skewed as seen in Fig. 1 to supplement the force exerted by the magnetized wobble plate 20 urging the workpiece against the wobble plate.

Also connected to the rock shaft **52** is an ejector **55** having an operative end **56** which raises between the work support elements **18** and **19** against the workpiece **10** to eject it from operative position after the refining operation is completed. For this purpose, the rock shaft **52** is rotated by suitable means (not shown) which also withdraws the pressure roll **50** from the workpiece so that it may be ejected by the ejector **55**.

During the grinding operation the switches **40** and **41** are closed, thereby energizing the magnetic coil **35** and the wobble plate **20**, holding the workpiece against the wobble plate **20** so that it may be driven by the wobble plate. The switches **40** and **41** are held closed by the ejector **55** in its downward position, as seen in Fig. 1, but when the rock shaft **52** is rotated clockwise, as seen in Fig. 2, to withdraw the roll **50** and raise the ejector **55** against the workpiece, the switches **40** and **41** are allowed to open, thus demagnetizing the coil **35** and the wobble plate **20**. When the switches **40** and **41** are open, current flows across the wires **44** and **45** and the resistances **42** and **43** tending to reverse the field in the magnet coil **35** and further demagnetizing the wobble plate **20**.

With certain shapes and types of workpieces and the use of a sufficiently strong magnetizing force, the pressure roll **50** may be dispensed with. In such case it is preferable to mount the axis of the wobble plate **20** and its spindle **24** slightly off center with respect to the axis of rotation of the workpiece **10**, thus providing a sliding frictional engagement between the face of the wobble plate and the end face **4** of the workpiece **10**, creating a downward force urging the workpiece against the work supports **15** and **16**. In other instances, it may be desirable to guide the workpiece **10** by power means applied to the roll **50** instead of to the wobble plate **20**. During grinding the tool **12** is rotated and fed relatively toward the work **10** by any conventional means not shown.

Another embodiment of the invention is shown in Figs. 4 and 5, showing a tool spindle **13***a* having two tools **12***a* and **12***b* for finishing internal surfaces **1***a* and **1***b* of two workpieces **10***a* and **10***b* which abut each other at end surfaces **5***a* and **5***b*. The work may also comprise one piece having an over-all length equal to the combined lengths of the two workpieces. The axis of rotation of the work is determined by a pair of work supports **15***a* and **16***a* each having a support surface **18***a* and **19***a*. The support surface **18***a* straddles the line L_1 which is normal to the line F_1 along which the tools **12***a* and **12***b* are fed into the work, and the support surface **19***a* is substantially in the line of feed F_1, these two support surfaces thereby tending to eliminate errors due to irregulariites in the peripheral surface **3***a* of the work with which they are in contact and providing support for the work against the force exerted by the tool. The end face **4***b* of the workpiece **10***b* abuts against a wobble plate **20***a* comprising a series of permanent magnets **28** circumferentially arranged with a loose fit in a non-magnetic separator **31***a* around the face of the wobble plate **20***a* with the end of the magnets **28** abutting against the plate **20***a*. The wobble plate **20***a* has a semi-spherical ball joint connection **21***a* cooperating with a recess **22***a* in the enlarged end **23***a* of a spindle **24***a* having a driving pulley **25***a*. A pair of reeds **30***a* resiliently connect the wobble plate **20***a* with the end **23***a* of the spindle so that the wobble plate may be rotated to drive the work while at the same time following the out-of-square end face **4***b* of the work. Since the magnets **28** fit freely in the separator **31***a*, the latter being of a different material, is free to expand and contract independently of the magnets.

The spindle **24***a* is mounted in self-aligning bearings **26***a* and with adequate clearance **29** along its surface to allow the wobble plate **20***a* to center itself with respect to the axis of rotation of the workpiece.

A second rotating wobble plate **60** is resiliently urged against an end surface **6** of the work thereby forcing the work against the wobble plate **20***a*. The wobble plate **60** has a flange portion **61** received loosely in a circular chamber **62** formed by a casing **67** so that the wobble plate **60** can move angularly with respect to the axis of rotation of the work and also radially in order to center itself with respect to said axis.

In operation, air under pressure is received from pump means **63** and a valve **64** and lines **65** to the right of the flange **61**, as seen in Fig. 4, thus forcing the wobble plate **60** to the left against the work. In this condition the air exhausts through a line **66**. When the work is to be removed from the machine, the valve **64** is reversed admitting pressure through the line **66** retracting the wobble plate **60** to the right away from the work. Thus, the force of the wobble plate **60** supplements the magnetic force of the wobble plate **20***a* to maintain the work in driving engagement with the wobble plate **20***a*.

An adjustably positioned magnet **50**, located between the work supports **15***a* and **16***a* and adjacent but not touching the peripheral surface of the work, serves to urge the workpiece down onto the support surfaces **18***a* and also to increase the friction of the work on the supports thereby to prevent over-running of the work caused by the tangential force exerted by the tools **12***a* and **12***b*.

A further modification is shown in Figs. 6, 7 and 8 for grinding the internal surface of a long workpiece **10***c*. This machine includes a grinding tool **12***c* on a spindle **13***c* applicable to an inner surface of the workpiece, two pairs of supports **15***c* and **16***c* each including arcuate support surfaces **18***c* and **19***c* straddling a line through the center of the work normal to the line of feed of the wheel into the work, a wobble plate **20***c* and a pair of end rolls **70** and **71** resiliently bearing against an end surface **6***c* of the work forcing its other end **4***c* against the bearing members **72** of hard metal inserted in the wobble plate **20***c*. The wobble plate **20***c* has a ball joint connection **21***c* with the enlarged end **23***c* of a work drive spindle **24** which is mounted in conventional bearings and driven by a pulley not shown. Also connecting the wobble plate **20***c* so that it may be rotated by the spindle, are a plurality of screws **73** and springs **74** providing resilient connections allowing the plate **20***c* to wobble on the ball joint **21***c*. An ejector **55***c*, having an operative end **56***c*, is pivoted on a rock arm **52***c*.

The rolls **70** and **71** are independently mounted to operate in sequence and to be independently adjusted for various sizes of workpiece and for pressure exerted. The axis of the rolls may be displaced to the left as shown in Fig. 6 from the axis of the work so that as the work rotates clockwise its contact with the rolls is part rolling and part sliding.

The sliding component is in an upward direction in the case of each roll, which, therefore, exerts a downward force against end surface **6***c* of the work, urging this end of the work against the pair of supports **15***c*. The other end of the work **4***c* is urged against the pair of supports **16***c* by plate **20***c* which is shown eccentric to the work. The roll **70** is mounted on an arm **80** adjustably secured by screws **81** movable up and down in a T-slot **82** in an arm **83** pivoted by reed pivots **84** and **85** to a frame portion **86**. The roll **71** is mounted on an arm **90** adjustably secured by screws **91** in a T-slot on an arm **93** pivoted to the frame portion **86** by reed pivots, indicated at **94** in Fig. 6, and similar to the reed pivots **84** and **85**. A spring **87** whose pressure is adjusted by a screw **88**, urges the arm **83** in a clockwise direction to force the roll **70** against the end face **6***c* of the work and a spring **97**, whose pressure is adjustable by a screw **98**, forces the roll **71** against the work. After the grinding operation is completed, a fluid pressure operated cylinder **100** operates to move a link **101** attached to a lever **102** fastened to the rock shaft **52***c*, to the left. Pivoted to the lever **102**

at 103 is a link 104 pivoted at 105 to the arm 93. Hence, movement of the link 101 to the left raises the ejector 55c to force the work from the machine and also moves the arm 93 counterclockwise, as viewed in Fig. 7, to retract the roll 71. As seen in Figs. 6 and 8, the arm 93 has a portion 110 overhanging the arm 83 with a gap between. This provides a lost motion so that the roll 71 is first retracted and then the overhanging portion 110 engages the arm 83 to retract the roll 70. This successive retraction of the rolls 70 and 71 facilitates workpiece loading because the roll 70, with less retraction, serves as a guide for inserting a new workpiece.

As best seen in Fig. 6, the center line or axis of rotation of the rolls 70 and 71 is offset relative to the axis of the work thus providing a component of force which urges the work downwardly against the support. The axis of rotation of the wobble plate 20c may also be offset thereby providing a downward force on the work at its opposite end.

Since the rolls 70 and 71 are able to follow an out-of-square end face 6c, the rolls are equivalent in function to the resiliently urging front wobble plate 60 in Fig. 4.

Figs. 9 and 10 show an alternate form of wobble back plate 20d, a non-magnetized type, which may be substituted for other forms illustrated; for instance, the wobble plate 20a in Fig. 4. It pivots on a pin 110 which connects it to an enlarged portion 23d of the spindle 24d allowing it to wobble in one plane. It has a pair of hardened work contact elements 111 with which an out-of-square surface 4d of the workpiece 10d is adapted to make contact. As seen in Fig. 10, the work contacts 111 are on a line normal to the axis of the pin 110 and, since the contact area is small, the line through the surfaces of the contacts 111 in effect provides a pivotal axis normal to the pivotal axis of the pin 110, so that the work contacts 111 may always be in contact at diametrically opposite points on an out-of-square work piece end surface.

Figs. 11 and 12 show a modification of the invention for grinding, by means of a wheel 146 on a rotary spindle 148 carried by a conventional wheelhead 149, the internal surface 1e of a workpiece 10e, such as a ball bearing inner race, while the latter is supported on an external surface 3e comprising an outer ball groove having a circular arcuate section. Since it is difficult to maintain accurately the axis of rotation of a short workpiece by supporting it on such a surface, the workpiece is held axially in alignment by urging its end face 4e, which is first made square to its axis of rotation, against a rotating back plate 120 having a spindle 124, the axis of which is fixed by supporting it in at least two sets of bearings 126 and 127. The driving face 128 of the back plate, against which the workpiece is urged, is therefore held square to the desired axis of rotation of the workpiece. The workpiece is radially supported to fix its center of rotation by a pair of arcuate supports 130 and 131 whose surfaces, as seen at 132 in Fig. 11, have a rounded section conforming to the cross section of the support surface 3e of the workpiece.

The workpiece 10e is urged against the back plate 120 by a rotating wobble plate 140 which is free to wobble and to center itself radially in a chamber 142 formed by a casing 147. The wobble plate 140 is urged against the workpiece to force the latter against the back plate 120 by air pressure furnished by a pump 143 through a valve 144, the construction of the front wobble plate 140 and associated mechanism, shown in Fig. 11, being the same as that of the wobble plate 60 shown in Fig. 4.

Figs. 13 and 14 show a modified form of support for use in the device shown in Figs. 11 and 12 in grinding a workpiece 10e. It comprises a support member 150 having a round support element 151 inserted therein conforming to the round section of the outer race surface 3e of the workpiece and the position of which may be adjusted by a set screw 152, and also a support member 155 having a shoe member 156 pivoted at 157, with a pair of round support elements 160 and 161 inserted therein also conforming with the ball race surface 3e of the workpiece. The position of the support member 155 may be adjusted by a set screw 165 and, since the support elements 160 and 161 are free to pivot around the pin 157, they maintain themselves in contact with the work surface 3e. The support members 150 and 155 are arranged to straddle a line L through the center of the workpiece normal to the line of feed F of the wheel into the work, and the support member 155 is positioned so that the support elements 160 and 161 support the workpiece substantially in the line of force exerted by the wheel against the work.

In Figs. 11–14, the workpiece is urged radially against the supports 130, 131 and 150, 160, 161 by a component of force exerted frictionally by the backplate 128, which is mounted for this purpose slightly eccentrically to the axis of rotation of the workpiece.

The wobble plates 60 (Fig. 4) and 140 (Fig. 11) have been described as being free to center themselves radially with respect to the axis of the workpiece, but the work may be so located with respect to such a wobble plate that the wobble plate will also urge the work against the supports. This we prefer to do when the work is of such a nature that other means for urging it against the support might be unsuitable or inadequate. For this purpose the casing 147, Fig. 11, may be located concentric with spindle 120 which, as described and shown in Fig. 12, is eccentric to the workpiece 10e, also for this purpose. The radial clearance around the flange of the wobble plate 140 in the casing 147 must then be small enough to keep the wobble plate from centering itself with the workpiece.

We claim:

1. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, an end plate positioned to be abutted by one end of a workpiece on the support means, said end plate being rotatably supported by means to allow it to wobble freely within limits from its axis of rotation while fixing it in a direction axially of said workpiece and being thereby capable of maintaining said abutting contact when said workpiece end is out of square with its axis without disturbing the position of the workpiece on the support means, a magnet associated with said end plate to provide frictional engagement between the end plate and the workpiece, means to rotate the end plate thereby to drive the workpiece, a grinding tool and means to apply the grinding tool to said inner workpiece surface.

2. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, an end plate positioned to be abutted by one end of a workpiece on the support means, said end plate being rotatably supported by means to allow it to wobble freely within limits from its axis of rotation while fixing it in a direction axially of said workpiece and being thereby capable of maintaining said abutting contact when said workpiece end is out of square with its axis without disturbing the position of the workpiece on the support means, yieldable means to urge the workpiece against the end plate, said yieldable means comprising a pair of end rolls arranged to press against the other end of the workpiece, means to rotate the workpiece on said support means, a grinding

tool and means to apply the grinding tool to said inner workpiece surface.

3. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, an end plate positioned to be abutted by one end of a workpiece on the support means, said end plate being rotatably supported by means to allow it to wobble freely within limits from its axis of rotation while fixing it in a direction axially of said workpiece and being thereby capable of maintaining said abutting contact when said workpiece end is out of square with its axis without disturbing the position of the workpiece on the support means, a yieldable roll arranged to make contact with said outer preformed surface to urge the workpiece against the work support means, said yieldable roll being skewed with its axis at an angle to the axis of the workpiece thereby exerting a component of force exerting the workpiece against the end plate, means to rotate the workpiece on said support means, a grinding tool, and means to apply the grinding tool to said inner workpiece surface.

4. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, an end plate positioned to be abutted by one end of a workpiece on the support means, said end plate being rotatably supported by means to allow it to wobble freely within limits from its axis of rotation while fixing it in a direction axially of said workpiece and being thereby capable of maintaining said abutting contact when said workpiece end is out of square with its axis without disturbing the position of the workpiece on the support means, a nonpermanent magnet associated with said end plate to provide frictional engagement between the end plate and the workpiece, means to magnetize and demagnetize said magnet, means to rotate the end plate thereby to drive the workpiece, a grinding tool and means to apply the grinding tool to said inner workpiece surface.

5. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, an end plate positioned to be abutted by one end of a workpiece on the support means, said end plate being rotatably supported by means allowing it to wobble freely within limits from its axis of rotation while fixing it in a direction axially of said workpiece and being thereby capable of maintaining said abutting contact when said workpiece end is out of square with its axis without disturbing the position of the workpiece on the support means, a nonpermanent magnet associated with said end plate, means to magnetize and demagnetize said magnet to provide frictional engagement between the end plate and the workpiece, means to rotate the end plate thereby to drive the workpiece, a grinding tool, means to apply the grinding tool to said inner workpiece surface, an ejector for the workpiece, and means operable to demagnetize said magnet and then to actuate said ejector.

6. In an internal grinding machine for refining the inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution,

and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, an end plate positioned to be abutted by one end of a workpiece on the support means, said end plate being rotatably supported by means to allow it to wobble freely within limits from its axis of rotation while fixing it in a direction axially of said workpiece and being thereby capable of maintaining said abutting contact when said workpiece end is out of square with its axis without disturbing the position of the workpiece on the support means, a magnet positioned to urge the workpiece against the support means, yieldable means to urge the workpiece against the end plate, means to rotate the workpiece on said support means, a grinding tool, and means to apply the grinding tool to said inner workpiece surface.

7. In an internal grinding machine for refining the inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, an end plate positioned to be abutted by one end of a workpiece on the support means, said end plate having a spindle and flexible means drivingly connecting it to the spindle including a ball-and-socket joint to allow it to wobble freely within limits from its axis of rotation and to fix it is a direction axially of said workpiece, said end plate being thereby capable of maintaining said abutting contact when said workpiece end is out of square with its axis without disturbing the position of the workpiece on the support means, yieldable means to urge the workpiece against the end plate, means to rotate the spindle and thereby the workpiece, a grinding tool, and means to apply the grinding tool to said inner workpiece surface.

8. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially, a rotatable spindle having a thrust bearing, an end plate rotated by the spindle, a flexible joint between the end plate and spindle holding the end plate rigid endwise of the spindle and free to wobble relative to its axis so as to make continuous contact with an out-of-square end face of a workpiece in frictional abutting engagement against said end plate, said end plate being arranged to rotate about a center eccentric to the work axis to rotate the workpiece and at the same time to exert a component of force urging the workpiece onto said work support, means to drive the spindle and thereby the workpiece, a grinding tool and means to apply the grinding tool to said inner workpiece surface.

9. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said machine including a centerless work support to position the workpiece radially on a support determined fixed axis, a rotatable spindle having a thrust bearing, a back plate disposed transversely to said axis in proximity to said work support means and rotated by the spindle, a flexible joint having relatively movable parts between the back plate and the spindle holding the back plate rigid endwise of the spindle and movable to wobble relative to the spindle axis so as to make continuous contact with an out-of-square end face of a workpiece on the support means and in frictional abutting engagement against said back

plate, yieldable means to urge the workpiece against the back plate, means to drive the spindle and thereby the workpiece, an internal grinding tool, a tool spindle substantially parallel to said fixed axis to support the tool, and means to move the tool spindle parallel and then transversely relative to the said rotatable spindle to apply the tool to a said inner workpiece surface.

10. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said workpiece having an outer preformed surface of revolution, and in combination, fixed work support means having an arcuate concave surface arranged substantially to conform with said outer preformed surface and to extend circumferentially in contact therewith sufficiently to bridge irregularities thereon and to position the workpiece radially on a support determined fixed axis, a rotatable spindle having a thrust bearing, a back plate disposed transversely to said axis in proximity to said work support means and rotated by the spindle, a flexible joint having relatively movable parts between the back plate and the spindle holding the back plate rigid endwise of the spindle and movable to wobble relative to the spindle axis so as to make continuous contact with an out-of-square end face of a workpiece on the support means and in frictional abutting engagement against said back plate, yieldable means to urge the workpiece against the back plate, means to drive the spindle and thereby the workpiece, an internal grinding tool, a tool spindle substantially parallel to said fixed axis to support the tool, and means to move the tool spindle parallel and then transversely relative to the said rotatable spindle to apply the tool to a said inner workpiece surface.

11. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said machine including a centerless work support to position a workpiece radially, an axially fixed rotatable spindle carrying axially immovably with respect thereto a back plate disposed with respect to the work support to make contact with one end of a said workpiece on said support and to provide in cooperation with the centerless support a substantially fixed support determined axis for said workpiece, said spindle and back plate being rotatable on an axis eccentric to said support determined axis so as to drive said workpiece and simultaneously to force it against the said support, means to rotate the spindle, an axially yieldable front plate having a central aperture, means to carry the front plate generally coaxially with and transversely to said support determined axis on the side of the centerless support opposite said back plate thereby to make contact with the other end of said workpiece, a flexible connection between said last named means and said front plate simultaneously providing rotary, axial, radial and wobbling movement of the front plate with respect to said support determined axis, said wobbling movement being sufficient to allow the front plate to make continuous parallel contact with an out-of-square end face of a workpiece on the support means, means to urge the front plate toward the back plate to clamp a workpiece between them, a grinding tool having a tool spindle substantially parallel to said support determined axis, and means to introduce the grinding tool and tool spindle through said aperture and to apply the tool to a said inner workpiece surface.

12. In the combination as set forth in claim 11, said flexible connection comprising a radial flange surrounding said front plate and forming a piston, and a circular pressure chamber carried by said means to carry said front plate, said pressure chamber surrounding said back plate and flange with an excess of axial and radial clearance; and said means to urge the front plate toward the back plate comprising fluid pressure means connected to said pressure chamber.

13. In the combination as set forth in claim 11, said centerless support comprising at least one surface relative to which a said workpiece is rotatably slidable and which is concave in a plane normal to the support determined axis and convex in a plane containing the support determined axis and thereby arranged substantially to conform with a said outer preformed surface which is concave in a plane containing the workpiece axis.

14. In an internal grinding machine for refining an inner surface of revolution of a workpiece, and in combination, a centerless work support including support surface portions arranged in circumferential spaced relation thereby to provide radial support on a support determined fixed axis for a workpiece being rotated with its external surface in contact with said support, a rotatable spindle having a thrust bearing, a back plate disposed transversely to a said support determined axis in proximity to said work support and rotated by the spindle to make contact with one end of a workpiece on the support, a flexible joint having relatively movable parts between the back plate and the spindle holding the back plate rigid endwise of the spindle and movable to wobble relative to the spindle axis, an axially yieldable front plate having a central aperture, means to carry the front plate generally coaxially with and transversely to said support determined axis on the side of the centerless support opposite said back plate thereby to make contact with the other end of a said workpiece, a flexible connection between said last named means and said front plate simultaneously providing rotary, axial, radial and wobbling movement of the front plate with respect to said support determined axis, said wobbling movement being sufficient to allow the front plate to make continuous parallel contact with an out-of-square end face of a workpiece on the support means, means to urge the front plate toward the back plate to clamp a workpiece between them, means to drive said spindle to rotate a said workpiece, a grinding tool having a spindle substantially coaxial to said rotatable spindle, and means to introduce the grinding tool and spindle through said aperture and to apply the tool to a said inner workpiece surface.

15. In the combination as set forth in claim 14, said centerless work support also including support surface portions which are axially spaced and separated from each other with respect to a said support determined fixed axis providing a space therebetween and adjacent a workpiece seated in the support thereby arranged to make contact with axially separated portions of a said workpiece.

16. In an internal grinding machine for refining an inner surface of revolution of a workpiece, and in combination, a centerless work support including support surface portions arranged in both axial and circumferential spaced relation thereby to provide radial support on a support determined fixed axis for a workpiece being rotated with its external surface in contact with said support, a rotatable spindle having a thrust bearing, a back plate disposed transversely to a said support determined axis in proximity to said work support and rotated by the spindle, a flexible joint having relatively movable parts between the back plate and the spindle holding the back plate rigid endwise of the spindle and movable to wobble relative to the spindle axis so as to make continuous contact with an out-of-square end face of a workpiece on the support and in frictional abutting engagement against said back plate, yieldable means to urge the workpiece against the back plate, means to drive the spindle and thereby the workpiece, an internal grinding tool, a tool spindle substantially parallel with the rotatable spindle, and means to move the grinding tool and spindle parallel and then transversely relative to the spindle to apply the tool to a said inner workpiece surface.

17. In the combination as set forth in claim 16, said end plate being arranged to rotate about a center which is eccentric to the support determined work axis to rotate the workpiece and at the same time to exert a compo-

nent of force urging the workpiece onto said work support.

18. In the combination as set forth in claim 16, said flexible joint including a ball, a socket receiving said ball, and resilient means to hold the ball in the socket and to prevent rotation of the back plate relative to the spindle thereby allowing the back plate to wobble relative to the spindle while the spindle drives the back plate.

19. In the combination as set forth in claim 16, said means to urge the workpiece against the back plate comprising a magnet associated with the back plate and disposed behind the operative face of the back plate thereby operative to hold a said workpiece in frictional engagement with the back plate.

20. In the combination as set forth in claim 16, said means to urge the workpiece against the back plate comprising a pair of rolls arranged with respect to said work support to make contact with the opposite end of a said workpiece, and means to urge each of said rolls independently of the other against said workpiece whereby said rolls are capable of following an out-of-square said opposite end of said workpiece.

21. In the combination as set forth in claim 16, the support surface portions of said centerless work support being axially separated from each other providing a space therebetween and adjacent a workpiece seated in the support and thereby arranged to make contact with axially separated portions of a said workpiece.

22. In the combination as set forth in claim 16, a magnet positioned in said space between said axially separated support surface portions to urge a said workpiece against the centerless work support.

23. In an internal grinding machine for refining an inner surface of revolution of a workpiece, said machine including a centerless work support to position a workpiece radially, an axially fixed rotatable spindle carrying immovably with respect thereto a back plate disposed with respect to the work support to make contact with one end of a said workpiece on said support and to provide in cooperation with the centerless support a substantially fixed support determined axis for said workpiece, said spindle and said back plate being rotatable

on an axis eccentric to said support determined axis so as to force said workpiece against said support, an axially yieldable front plate having a central aperture, means to carry the front plate generally coaxially with and transversely to said support determined axis on the side of the centerless support opposite said back plate thereby to make contact with the other end of said workpiece, a flexible connection between said last named means and said front plate simultaneously providing rotary, axial, radial and wobbling movement of the front plate with respect to said support determined axis, said wobbling movement being sufficient to allow the front plate to make continuous parallel contact with an out-of-square end face of a workpiece on the support means, means to urge the front plate toward the back plate to clamp a workpiece between them, means to rotate one of said plates to drive the workpiece, a grinding tool having a tool spindle substantially parallel to said support determined axis, and means to introduce the grinding tool and tool spindle through said aperture and to apply the tool to a said inner workpiece surface.

References Cited in the file of this patent

UNITED STATES PATENTS

1,611,122	Mirfield	Dec. 14, 1926
1,814,350	Theler	July 14, 1931
1,843,079	Booth	Jan. 26, 1932
1,938,763	Haas	Dec. 12, 1933
1,999,320	Dunham	Apr. 30, 1935
2,039,223	Hutchinson	Apr. 28, 1936
2,179,625	Groden	Nov. 14, 1939
2,478,607	Theler	Aug. 9, 1949
2,635,395	Arms	Apr. 21, 1953
2,646,652	Blood	July 28, 1953
2,657,504	Cadman	Nov. 3, 1953
2,706,369	Dix	Apr. 19, 1955
2,715,304	Dix	Aug. 16, 1955
2,723,499	Dix	Nov. 15, 1955

FOREIGN PATENTS

630,805	Germany	June 6, 1936