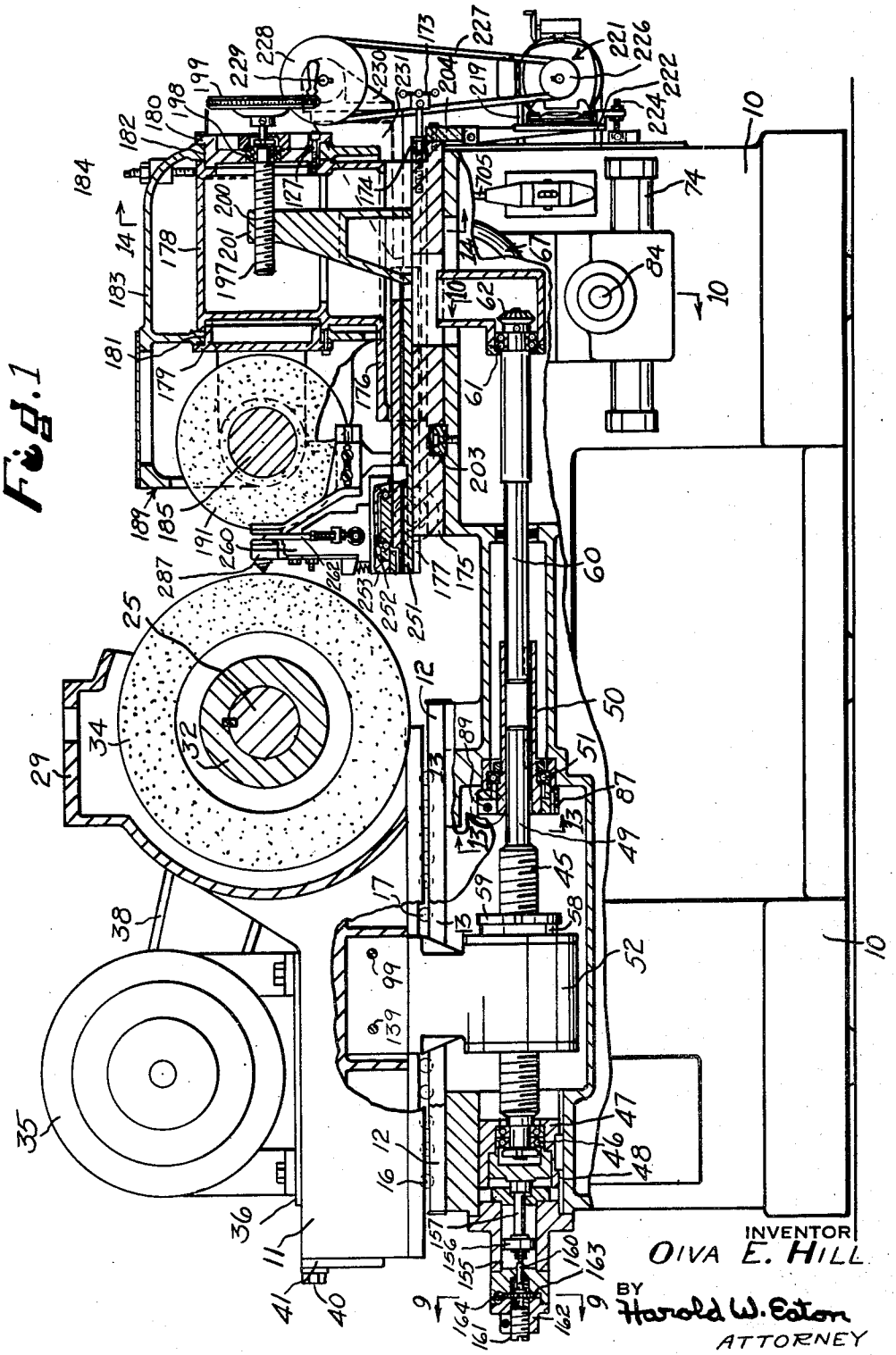
May 13, 1958 O. E. HILL 2,834,159

CENTERLESS GRINDING MACHINE

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Fig. 1



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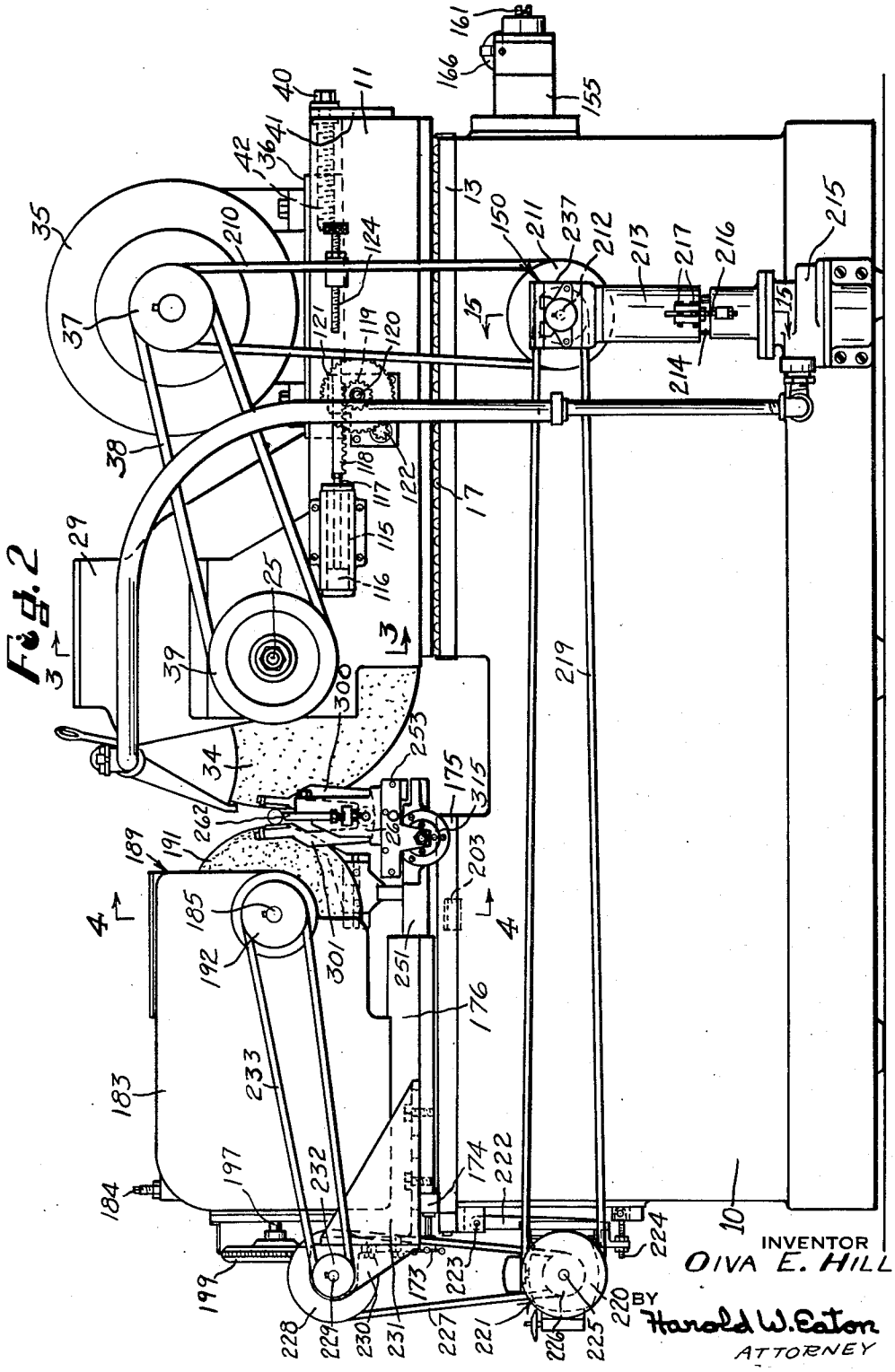


Fig. 2

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CENTERLESS GRINDING MACHINE

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Fig. 3

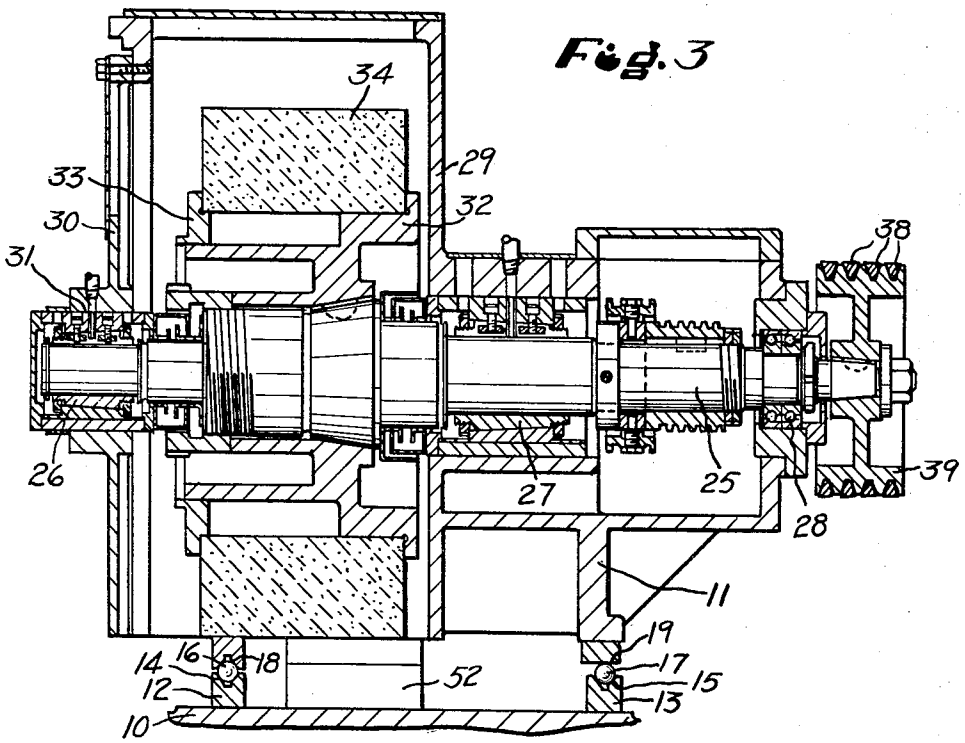
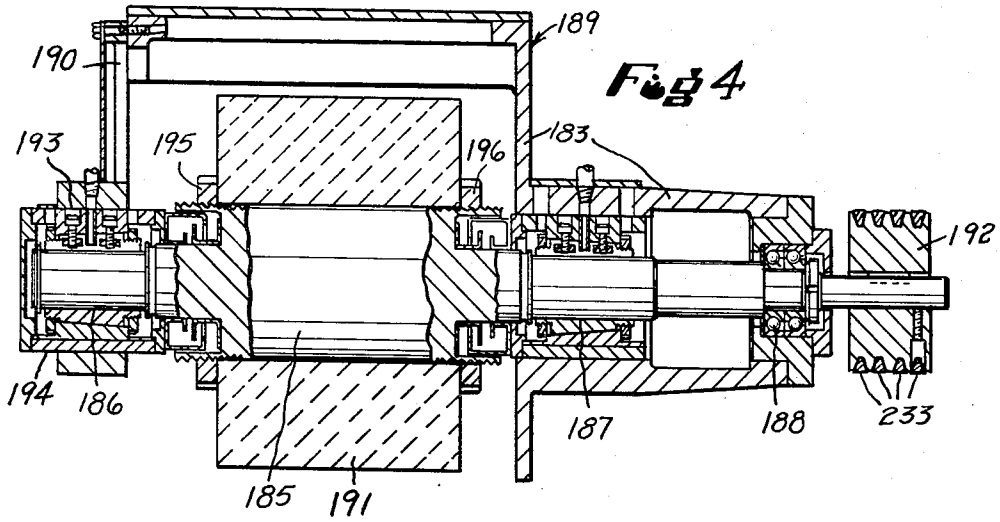


Fig 4



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CENTERLESS GRINDING MACHINE

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Fig. 5

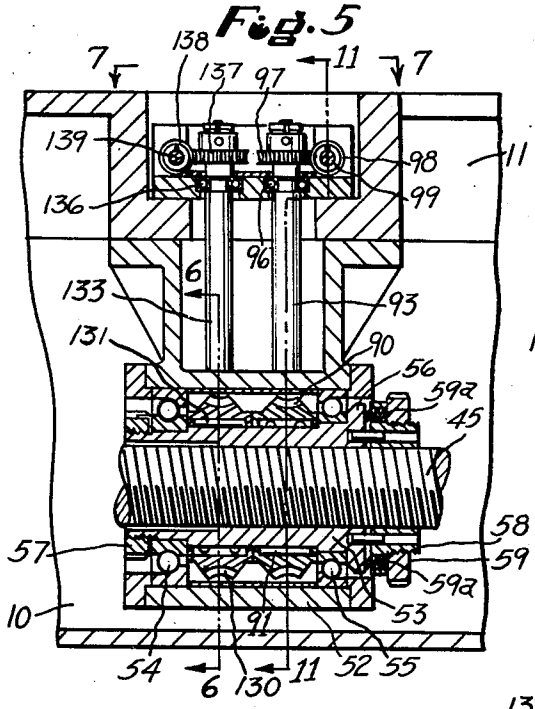


Fig. 7

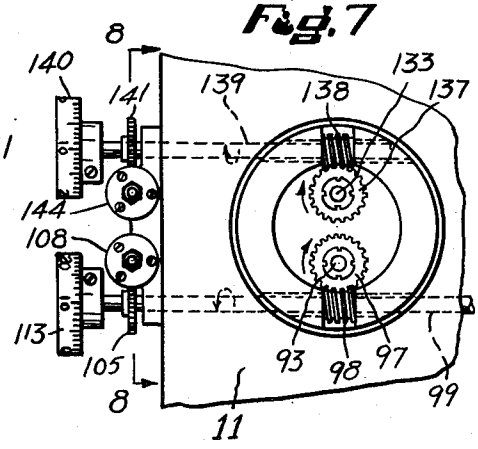


Fig. 8

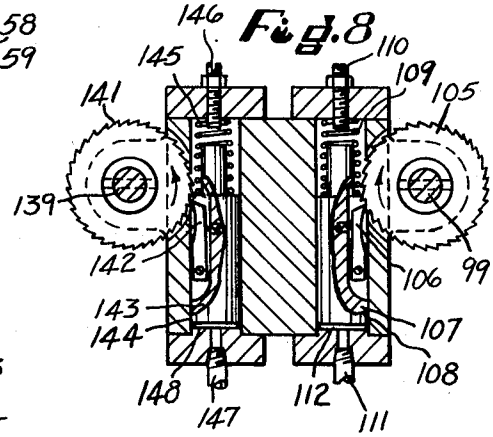


Fig. 6

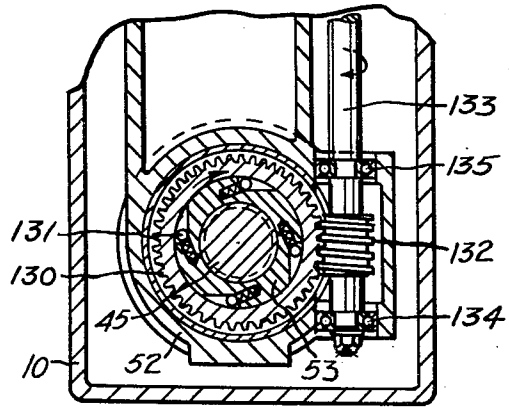
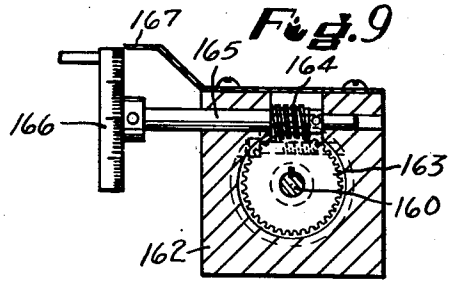


Fig. 9



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CENTERLESS GRINDING MACHINE

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Fig. 10

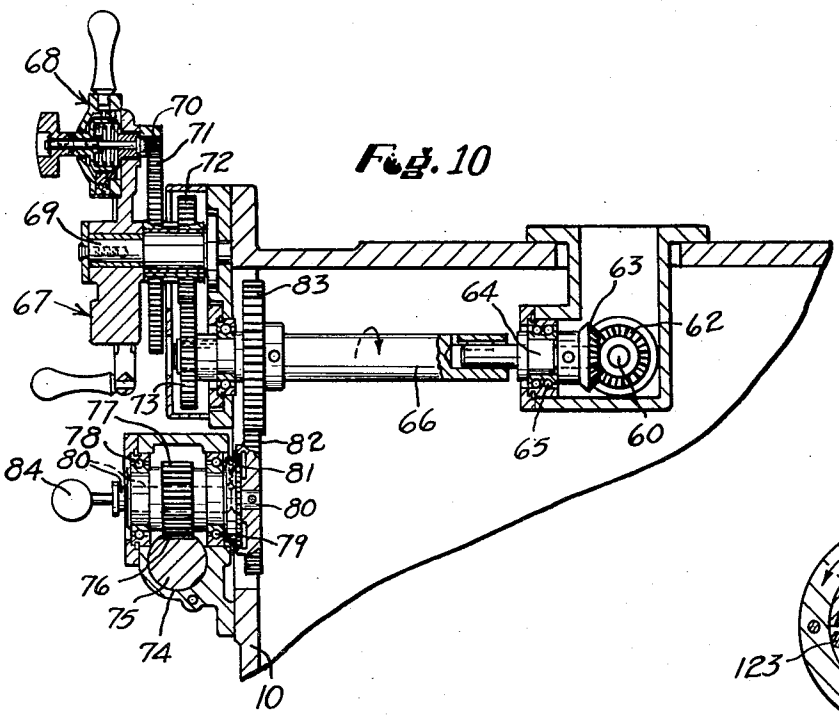


Fig. 12

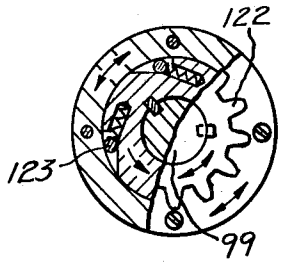
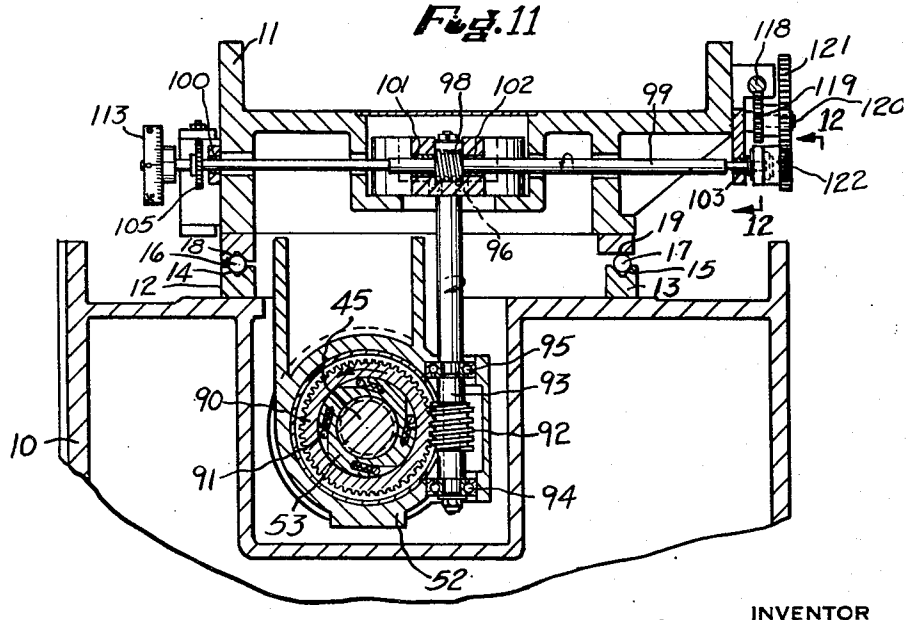


Fig. 11



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CENTERLESS GRINDING MACHINE

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Fig. 14

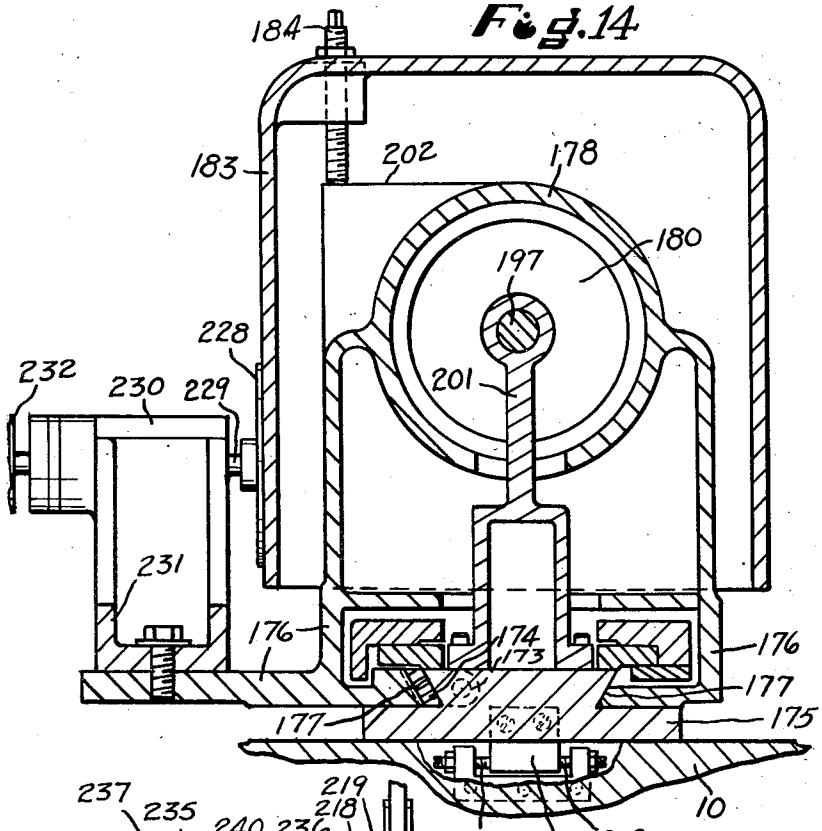
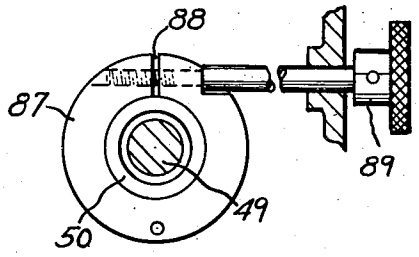


Fig. 13



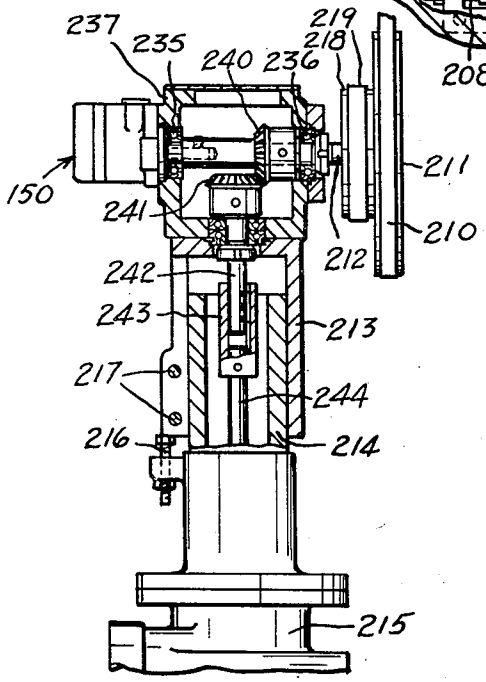


Fig. 15

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Fig. 16

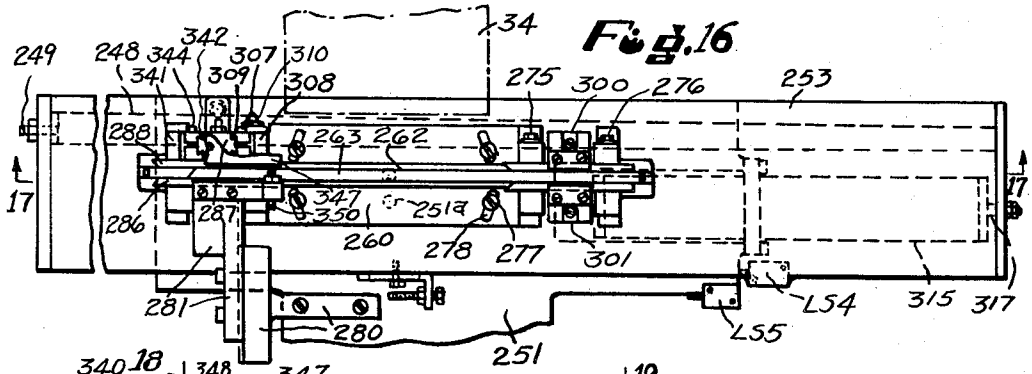


Fig. 17

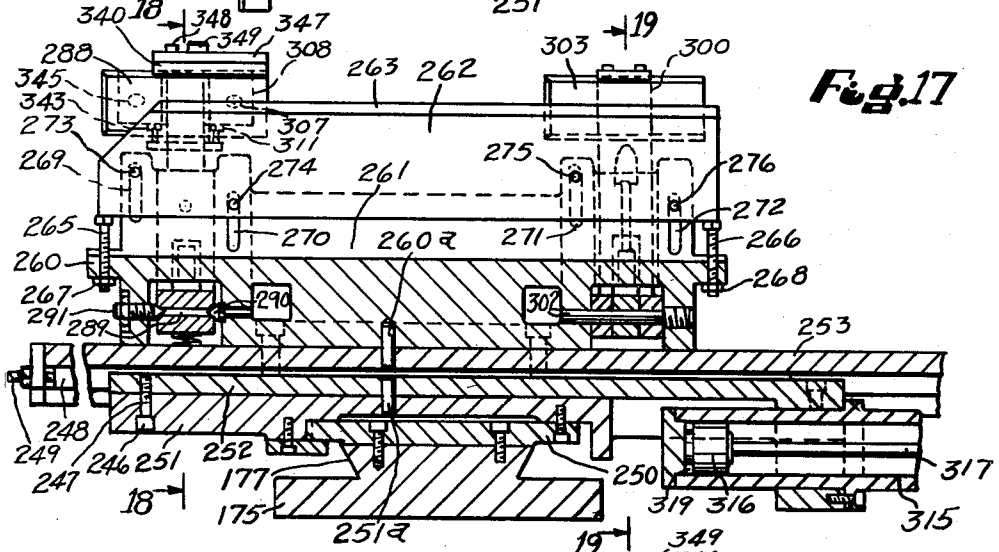
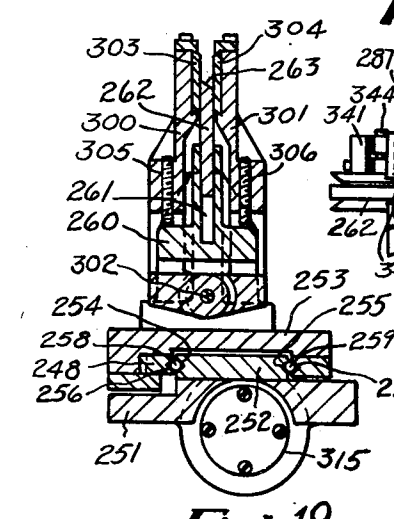


Fig. 20



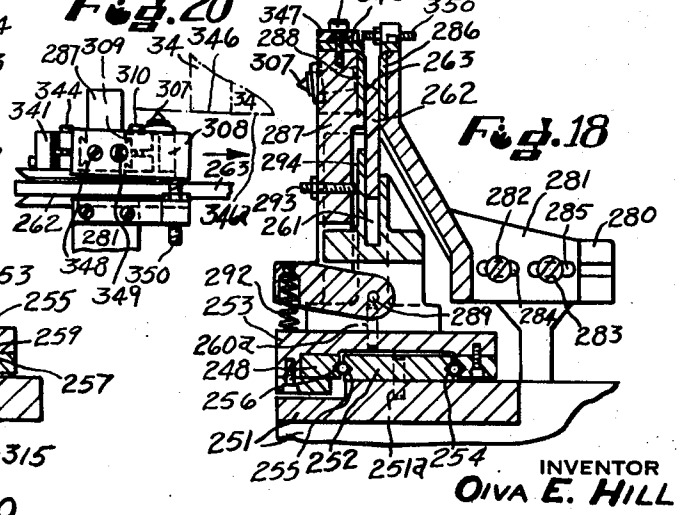


Fig. 18

Fig. 19

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Fig. 21

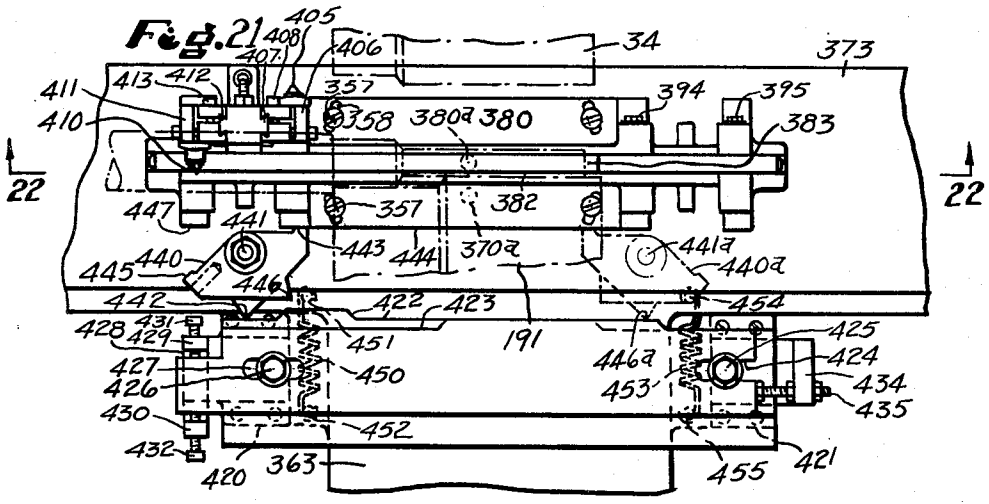


Fig. 22

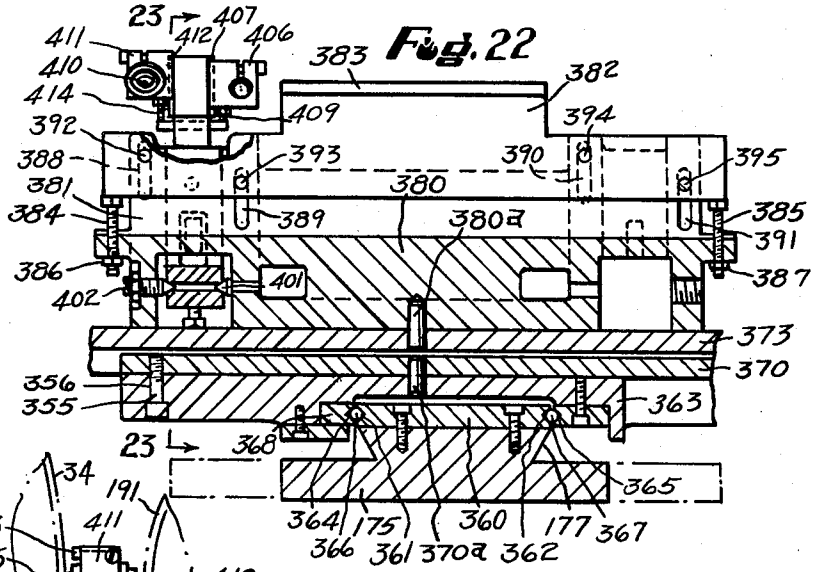
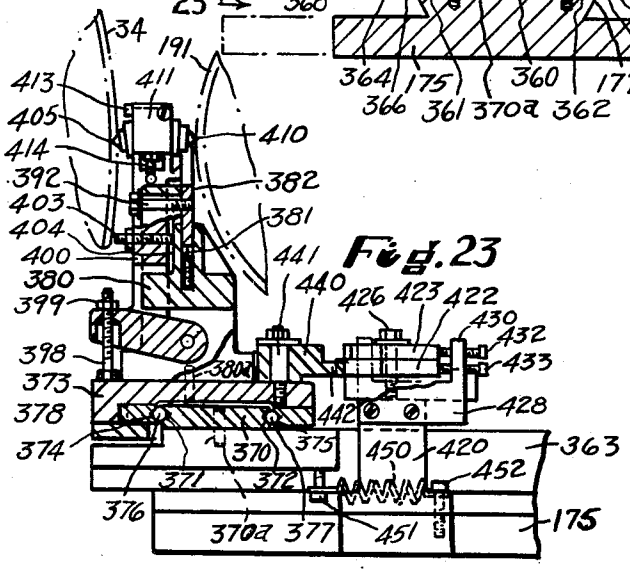


Fig. 23



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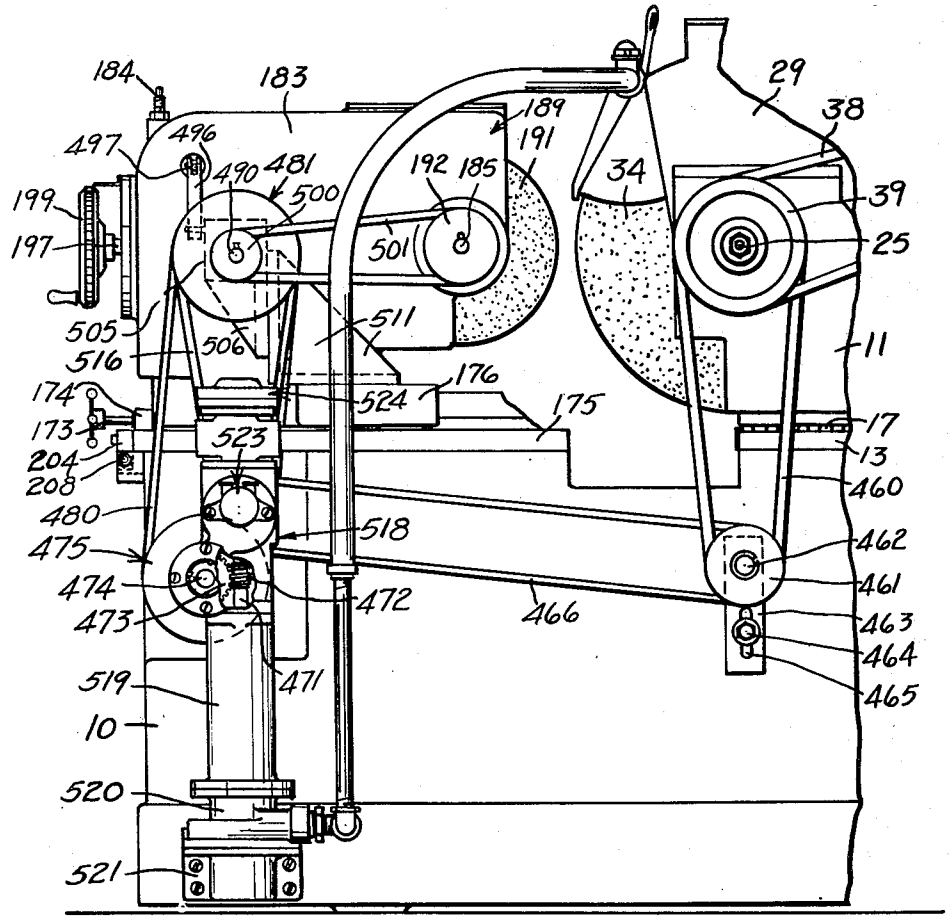


Fig. 24

INVENTOR
OIVA E. HILL

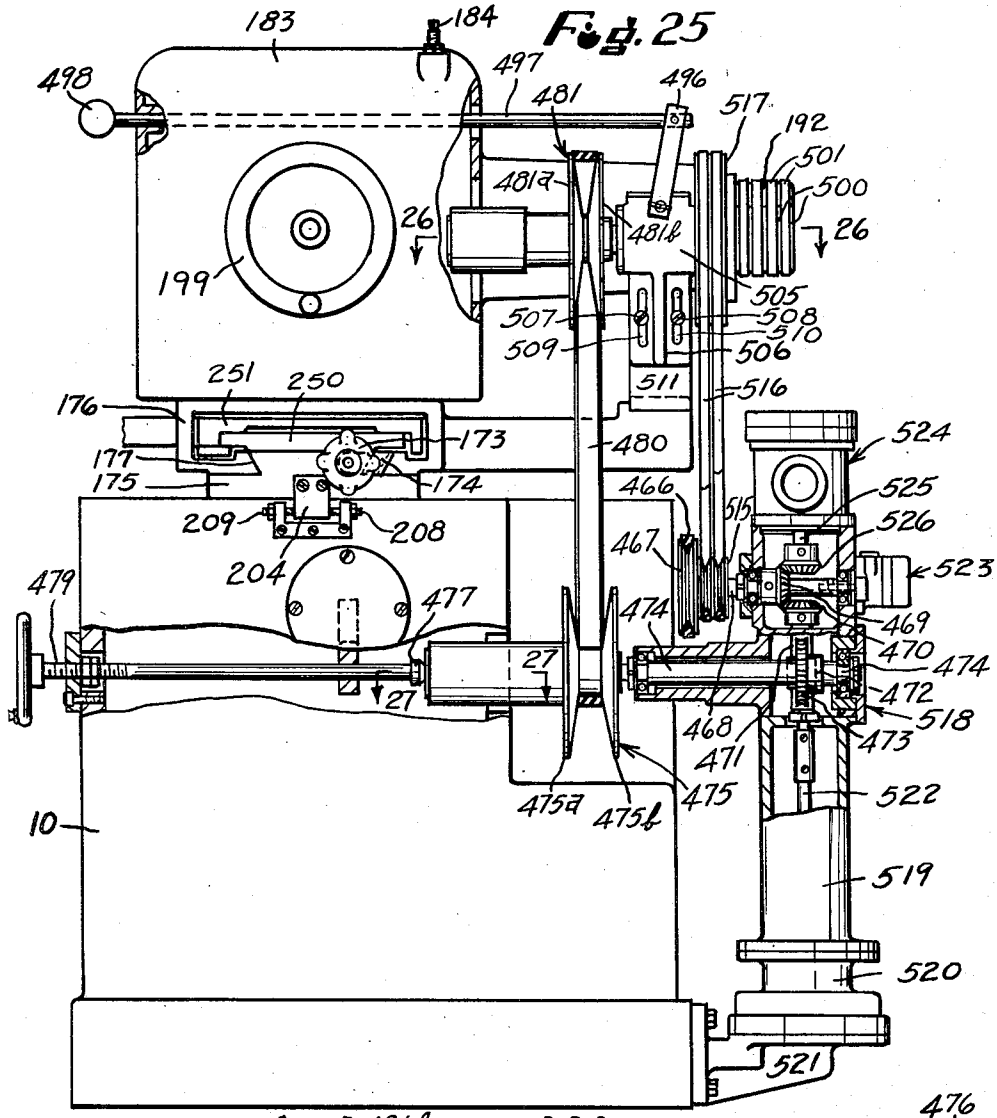
BY
Harold W. Eaton
ATTORNEY

May 13, 1958 O. E. HILL 2,834,159

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Fig. 25



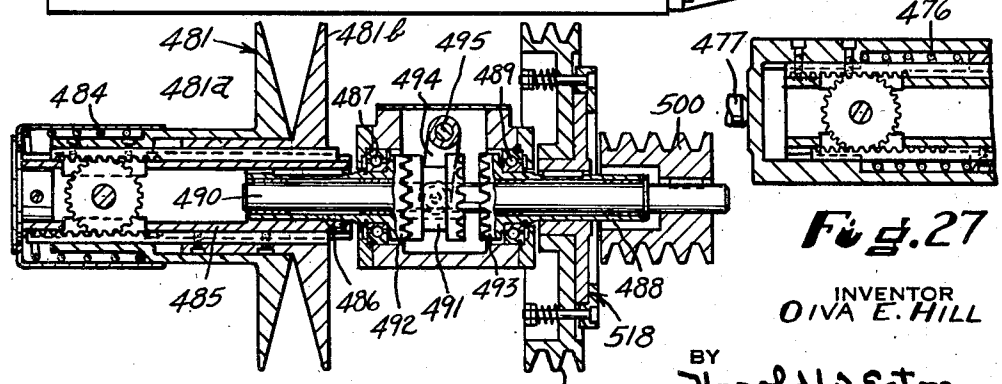


Fig. 26

Fig. 27

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CENTERLESS GRINDING MACHINE

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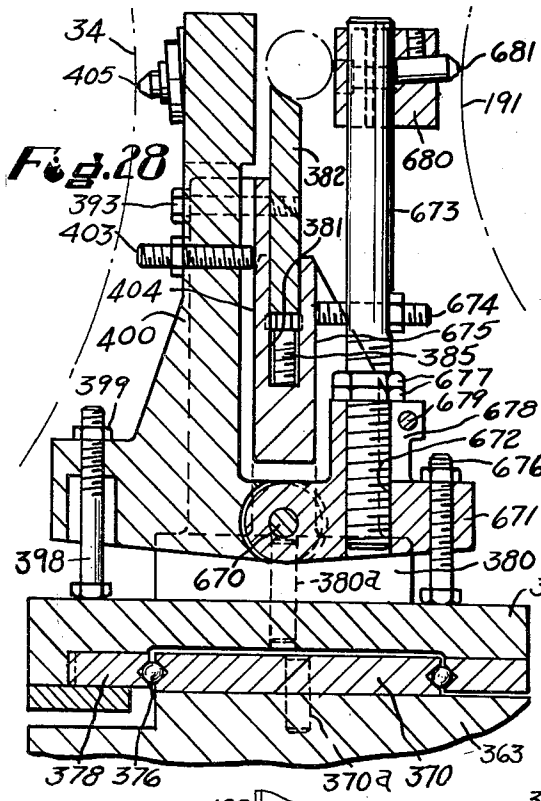


Fig. 28

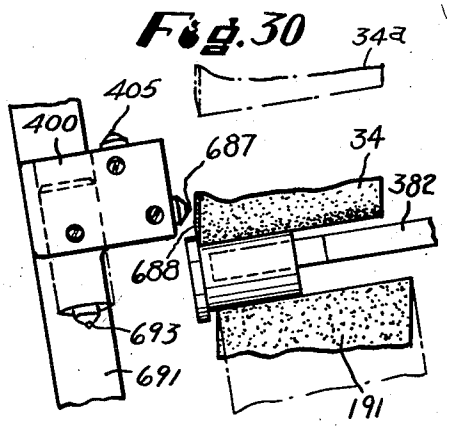


Fig. 30

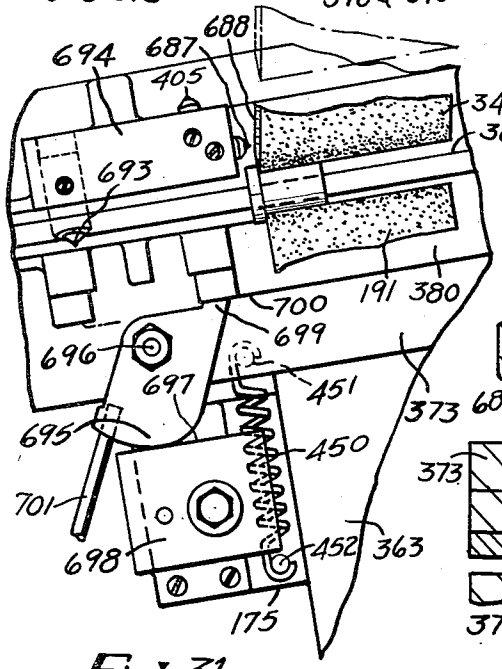


Fig. 31

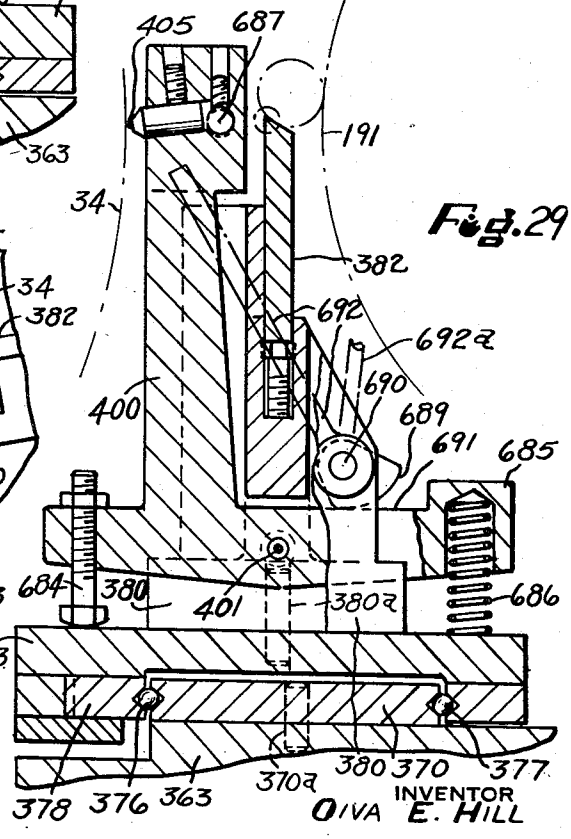


Fig. 29

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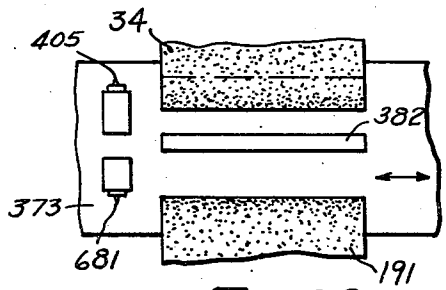


Fig. 32

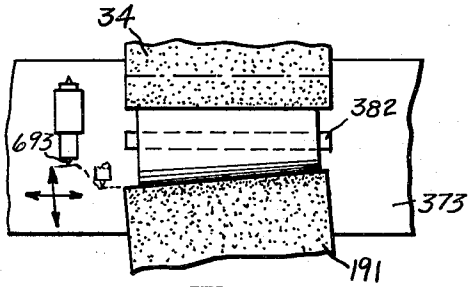


Fig. 34

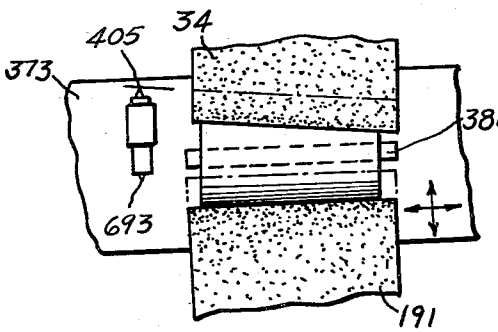


Fig. 33

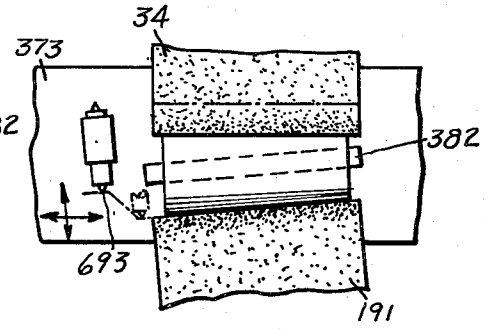


Fig. 35

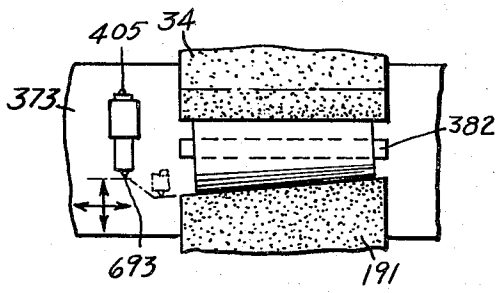


Fig. 36

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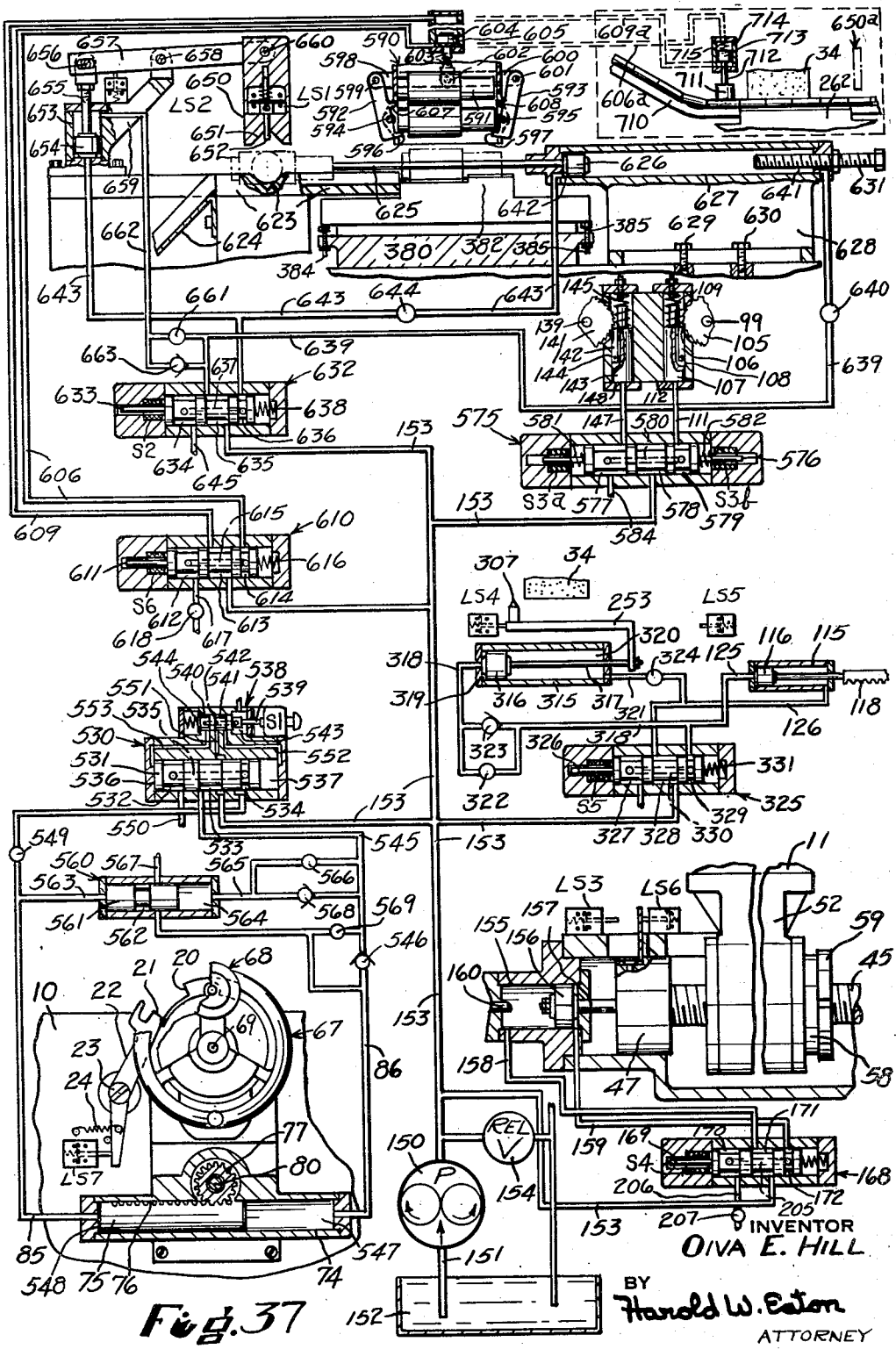


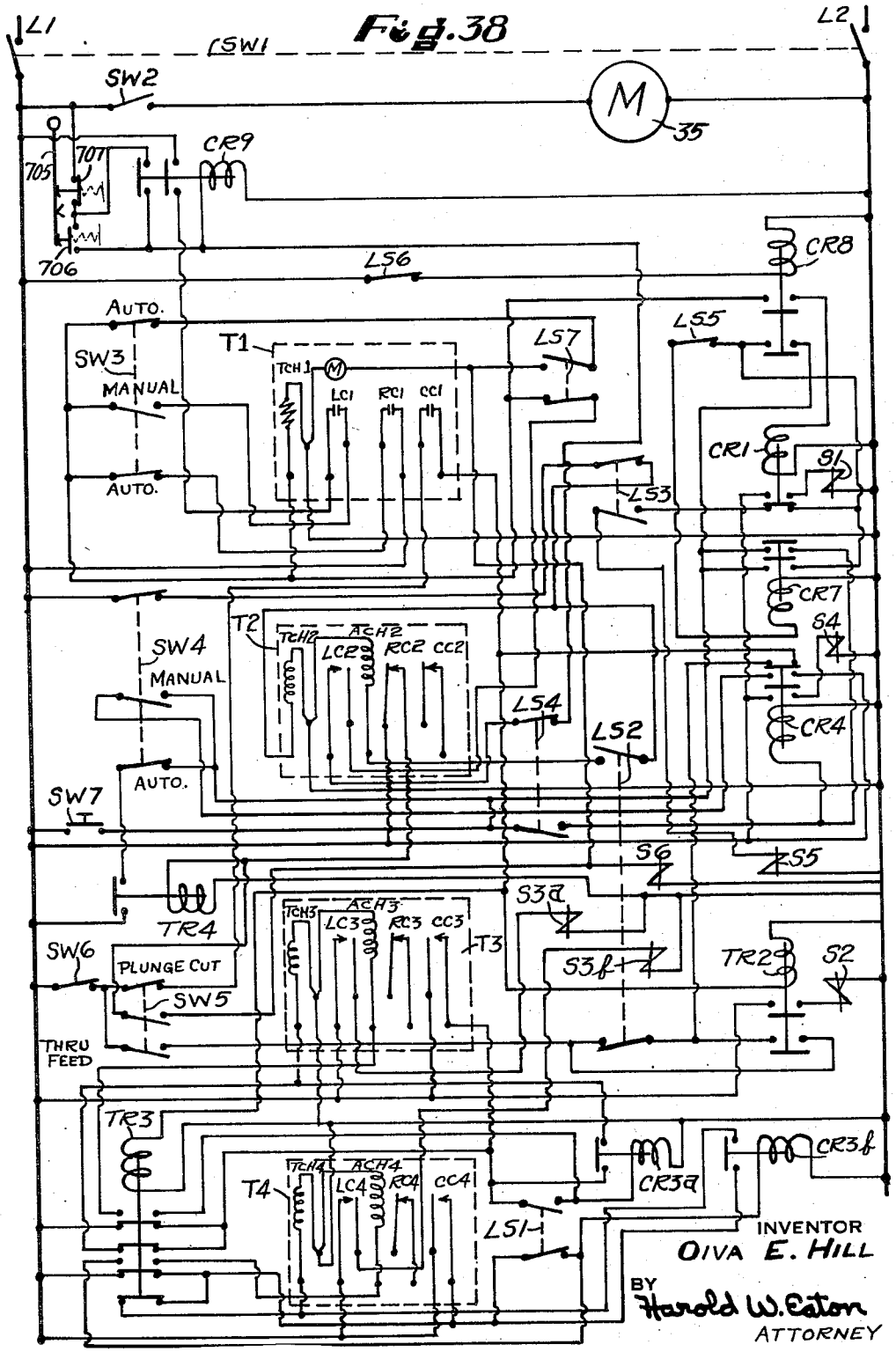
Fig. 37

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Fig. 38



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United States Patent Office 2,834,159 Patented May 13, 1958

2,834,159

CENTERLESS GRINDING MACHINE

Oiva E. Hill, West Boylston, Mass., assignor to Norton Company, Worcester, Mass., a corporation of Massachusetts

Application April 16, 1956, Serial No. 578,412

27 Claims. (Cl. 51—103)

The invention relates to grinding machines, and more particularly to centerless grinding machines.

One object of the invention is to provide a small and throughly practical centerless grinding machine. Another object is to provide a centerless grinding machine which may be set up for either straight-through or plunge-cut grinding. Another object is to provide a simplified truing apparatus for truing both the grinding wheel and the regulating wheel. Another object is to provide a work size control mechanism automatically to control work size on either plunge-cut or straight-through grinding. Another object of the invention is to provide a work size control mechanism which is operative after a predetermined number of work pieces have been ground either over size or under size to automatically impart a compensating adjustment to the wheel feeding mechanism.

Another object is to provide an automatic wheel truing mechanism for truing the grinding wheel after a predetermined number of work pieces have been ground. Another object is to provide a compensating mechanism automatically to advance the grinding wheel before a truing operation is initiated. A further object of the invention is to provide a compensating mechanism automatically to impart a forward compensation to the wheel feeding mechanism when the ground work pieces are over size. Another object is to provide a compensating mechanism automatically to impart a rearward compensation adjustment to the wheel feeding mechanism when work pieces are ground under size. Another object is to provide an independent forward and rearward compensating mechanism for the wheel feeding mechanism which is automatically controlled by the work size mechanism. Other objects will be in part obvious, or in part pointed out hereinafter.

One embodiment of the invention has been illustrated in the drawings;

Fig. 1 is a front elevation of the centerless grinding machine, having parts broken away and shown in section;

Fig. 2 is a rear elevation of the centerless grinding machine, showing the grinding and regulating wheel driving mechanism;

Fig. 3 is a vertical sectional view, on an enlarged scale, taken approximately on the line **3—3** of Fig. 2, through the grinding wheel spindle and bearings;

Fig. 4 is a vertical sectional view, on an enlarged scale, taken approximately on the line **4—4** of Fig. 2, through the regulating wheel spindle and bearings;

Fig. 5 is a fragmentary vertical sectional view, on an enlarged scale, through the feed screw and nut showing a portion of the feed compensating mechanism;

Fig. 6 is a fragmentary sectional view, taken approximately on the line **6—6** of Fig. 5, through the feed screw and nut;

Fig. 7 is a fragmentary plan view, taken approximately on the line **7—7** of Fig. 5 of the compensating mechanism;

Fig. 8 is a fragmentary vertical sectional view, on

an enlarged scale, taken approximately on the line **8—8** of Fig. 7, through the feed compensating mechanism;

Fig. 9 is a vertical sectional view, on an enlarged scale, taken approximately on the line **9—9** of Fig. 1, of the truing tool wear compensating adjusting mechanism;

Fig. 10 is a fragmentary vertical sectional view, on an enlarged scale, taken approximately on the line **10—10** of Fig. 1, through the wheel feeding mechanism;

Fig. 11 is a fragmentary vertical sectional view, taken approximately on the line **11—11** of Fig. 5 through the feed compensating mechanism;

Fig. 12 is a vertical sectional view, on an enlarged scale, taken approximately on the line **12—12** of Fig. 11, through the one-way ball clutch;

Fig. 13 is a fragmentary vertical sectional view, on an enlarged scale, taken approximately on the line **13—13** of Fig. 1, through the clamp on the feed screw mechanism;

Fig. 14 is a vertical sectional view, on an enlarged scale, taken approximately on the line **14—14** of Fig. 1, through the regulating wheel slide showing the slide arrangement and the pivotal support for the regulating wheel;

Fig. 15 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line **15—15** of Fig. 2, through a portion of the driving mechanism, showing the drive for the coolant and lubricant pumps;

Fig. 16 is a plan view, on an enlarged scale, of the work rest, work guides, and truing tool for use in a straight through grinding operation;

Fig. 17 is a vertical sectional view, on an enlarged scale, taken approximately on the line **17—17** of Fig. 16, showing the work rest and work guides in elevation;

Fig. 18 is a vertical sectional view, taken approximately on the line **18—18** of Fig. 17;

Fig. 19 is a vertical sectional view, taken approximately on the line **19—19** of Fig. 17;

Fig. 20 is a fragmentary plan view of the truing tool arranged for truing a slight taper on the entering portion of the grinding wheel;

Fig. 21 is a plan view, on an enlarged scale, of the work rest and the wheel truing apparatus for use in a plunge-cut grinding operation;

Fig. 22 is a vertical sectional view, taken approximately on the line **22—22** of Fig. 21, showing the work rest and truing apparatus in elevation;

Fig. 23 is a vertical sectional view, taken approximately on the line **23—23** of Fig. 22 through the work rest and the wheel truing apparatus;

Fig. 24 is fragmentary rear elevation of the grinding machine, showing a modified driving mechanism for the grinding wheel, regulating wheel and pumps;

Fig. 25 is an end elevation of the machine showing the modified driving mechanism having parts broken away and shown in section to illustrate the internal construction;

Fig. 26 is a horizontal sectional view, on an enlarged scale, taken approximately on the line **26—26** of Fig. 25;

Fig. 27 is a fragmentary sectional view, on an enlarged scale, taken approximately on the line **27—27** of Fig. 25;

Fig. 28 is a vertical sectional view of a modified form of the truing apparatus, in which the truing tool for the regulating wheel is independently adjusted;

Fig. 29 is a vertical sectional view, through the work rest, showing a modified form of wheel truing apparatus for truing the peripheral phases of the winding and regulating wheels and an angular face of the grinding wheel;

Fig. 30 is a fragmentary plan view of the truing apparatus as shown in Fig. 29;

Fig. 31 is a fragmentary plan view of a modification of the truing appartus as shown in Fig. 30 in which a

cam-actuated mechanism is provided to oscillate the side truing tool;

Fig. 32 is a fragmentary diagrammatic plan view showing the arrangement of the truing tools with relation to the grinding and regulating wheels and of the work rest as shown in Fig. 28;

Fig. 33 is a similar diagrammatic view showing a modification of the truing arrangement shown in Fig. 21, illustrating the relationship of parts for truing the grinding and regulating wheels for grinding the tapered work;

Fig. 34 is a similar diagrammatic plan view showing a modification of the arrangement shown in Fig. 21 in which the regulating wheel is swivelled and trued by use of a forming bar while the truing tool slide is swivelled to travel parallel to the axis of the grinding wheel to true the same;

Fig. 35 is a similar diagrammatic plan view showing a modification of the arrangement in Fig. 21 with the regulating wheel swivelled and trued by use of a forming bar while the truing slide is swivelled to travel in a direction parallel to the axis of the grinding wheel;

Fig. 36 is a similar diagrammatic plan view showing a modification of the arrangement in Fig. 21 in which the regulating wheel is trued by use of a forming bar and the grinding wheel is trued by a longitudinal movement of the truing tool slide;

Fig. 37 is a hydraulic diagram of the actuating mechanisms and the controls therefor; and

Fig. 38 is an electric wiring diagram.

A centerless grinding machine has been illustrated in the drawings comprising a base **10** which supports a transversely movable grinding wheel slide **11**. The base **10** is provided with a pair of spaced upwardly extending ribs **12** and **13**, which are provided with V-ways **14** and **15**, each of which supports a row of balls **16** and **17**. The under side of the wheel slide **11** is provided with a V-way **18** and a flatway **19** to form an anti-friction slideway for the wheel slide **11**.

The wheel slide **11** supports a rotatable wheel spindle **25** in a pair of spaced bearings **26** and **27**. The right-hand end of the wheel spindle **25** is supported by an anti-friction bearing **28**. A wheel guard **29** surrounds a grinding wheel **34** supported on the wheel spindle **25**. A removable cover plate **30** is detachably fastened to the left-hand side face of the wheel guard **29**. The cover plate **30** is provided with a cylindrical aperture **31**, which mates with the outside diameter of the bearing **26**. The grinding wheel spindle **25** is provided with a slidably keyed wheel mount **32**. A clamping flange **33** is screw threaded onto the wheel mount to facilitate clamping the grinding wheel **34** on to the mount **32** in fixed relation to the spindle **25**. In order to mount a grinding wheel **34** on the spindle **25**, the cover plate **30** is removed in an axial direction, without disturbing the bearing **26**, after which the grinding wheel **34** may be mounted on the mount **32**, and the flange **33** clamped to lock the wheel on the spindle.

A driving mechanism is provided for the wheel spindle **25** comprising an electric motor **35** which is mounted on a transversely adjustable motor base **36**, supported on the upper surface of the wheel slide **11**. The motor **35** is provided with a multiple V-groove pulley **37**, which is connected by multiple V-belts **38** with a pulley **39** which is mounted on the right-hand end of the wheel spindle **25** (Fig. 3).

An adjusting screw **40** is rotatably supported by a bracket **41** fastened to the right-hand or rear end of the wheel slide **11** (Fig. 2). The screw **40** is screw threaded into a threaded aperture **42** formed in the motor base **36**. By manipulating the screw **40**, the portion of the motor base **36** and the motor **35** may be adjusted to properly tension the driving belts **38**.

A feeding mechanism is provided for feeding the wheel slide **11** transversely. This mechanism comprises a rotatable feed screw **45** (Fig. 1), which is supported at its

left-hand end by an anti-friction bearing **46**, which is, in turn, supported by a slidably mounted sleeve **47**. The sleeve **47** is slidably keyed within a cylindrical aperture **48** formed in the base **10**.

A reduced cylindrical portion **49** of the feed screw **45** is slidably keyed within a rotatable sleeve **50**, which is journalled in an anti-friction bearing **51**, supported by the base **10**.

The wheel slide **11** is provided with a depending bracket **52** which rotatably supports a feed nut **53** (Fig. 5), in a pair of spaced anti-friction bearings **54** and **55**. The feed nut **53** is provided with an integral flange **56** at its right-hand end. The flange **56** bears against the right-hand surface of the bearing **55**. A collar **57** is screw threaded onto the left-hand end of the nut **53**. By manipulating the nut **57**, the thrust between the feed nut **53** and the bearings **54** and **55** may be readily adjusted.

A backlash eliminating mechanism is provided to take up backlash between the feed screw **45** and the feed nut **53**. This mechanism comprises a collar **58**, which is screw threaded onto the feed screw **45** (Fig. 5) and adjustable collar **59**, which is screw threaded onto the collar **58**. A plurality of compression springs **59***a* are provided between the collar **59** and the right-hand end face of the flange **56**. By manipulation of the collar **59**, the compression of the springs **59***a* may be varied as desired to eliminate backlash between the feed screw **45** and the feed nut **53**.

A manually operable feeding mechanism is provided for rotating the feed screw **45**. A shaft **60** is slidably keyed within the right-hand end of the sleeve **50** (Fig. 1). The right-hand end of the shaft **60** is supported by an anti-friction bearing **61** fixedly supported relative to the base **10**. A bevel gear **62** is mounted on the right-hand end of the shaft **60** (Fig. 1) and meshes with a bevel gear **63** (Fig. 10) mounted on the right-hand end of a rotatable shaft **64**. The shaft **64** is journalled in an anti-friction bearing **65**. A rotatable shaft **66** is slidably keyed onto the left-hand end of the shaft **64** (Fig. 10).

A manually operable feed wheel **67**, having a micrometer adjusting mechanism **68**, is rotatably supported by a shaft **69** on the front of the machine base. The feed wheel **67** is provided with a pinion **70** (Fig. 10) which meshes with a gear **71** rotatably supported on the shaft **69**. A gear **72** is fixedly mounted to rotate with the gear **71** on the shaft **69**. The gear **72** meshes with a gear **73** which is fixedly mounted on the left-hand end of the shaft **66**. It will be readily apparent from the foregoing disclosure that a rotary motion of the feed wheel **67** will be imparted through the gear mechanism above described to impart a rotary motion to the feed screw **45** so as to cause a transverse movement of the wheel slide **11** and the grinding wheel **34**.

A hydraulically operated mechanism is provided for feeding the grinding wheel **34** toward and from the work piece and regulating wheel during a plunge-cut grinding operation. This mechanism comprises a cylinder **74** (Figs. 10 and 24) which contains a slidably mounted piston **75**. The upper surface of the piston **75** is provided with rack teeth **76** which mesh with a gear **77**. The gear **77** is rotatably supported by a pair of space bearings **78** and **79**. A shaft **80** passes through a central hole in the gear **77**, and is connected at its right-hand end (Fig. 10) by a manually operable clutch **81**. The clutch **81** serves to engage or disengage a gear **82** to transmit rotary motion from the gear **77** to the gear **82**. The gear **82** meshes with a gear **83** mounted on the shaft **66**. It will be readily apparent from the foregoing disclosure that when fluid under pressure is passed through a pipe **85** into the left-hand end of the cylinder **74**, the piston **75** will be moved toward the right to impart a rotary motion through the gear mechanism above described, to rotate the feed screw **45** so as to cause a transverse feeding movement to be imparted to the wheel slide **11** and the grinding wheel **34**.

During movement of the piston **75** toward the right (Fig. 24) fluid is exhausted from the right-hand end of the cylinder **74** through a pipe **86**.

A clamping mechanism is provided for holding the sleeve **50** against rotary motion when the machine is set up for a straight through grinding operation. This clamping mechanism comprises a collar **87**, which surrounds the left-hand end of the sleeve **50**.

The collar **87** is provided with a slot **88**. A clamping screw **89** is provided to clamp the collar **87** to hold the sleeve **50** against rotation. This is particularly useful when the machine is set up for a straight through grinding operation where it is not desirable to have the feed screw **45** free to rotate. By providing this clamp, the feed screw **45** may be positively locked so that a compensating adjustment may be made by a rotary motion of the feed nut **53** as will be hereinafter described.

When the machine is set up for a plunge-cut grinding operation, the feed screw **45** may be manually rotated by rotation of the feed wheel **67** in a counter-clockwise direction. During the setting-up operation, the manually operable knob **84** (Fig. 10) may be shifted toward the right to disengage the clutch **81**. The feed wheel **67** is rotated in a counter-clockwise direction until a stop abutment **20**, adjustably supported by the feed wheel **67**, moves into engagement with a stop surface **21** on a pivotally mounted feed pawl **22**. The feed pawl **22** is pivotally supported by stud **23** on the front of the machine base, and is normally held in an operative position by means of a tension spring **24**. By manipulation of the micrometer feed adjusting mechanism **68**, the stop abutment **20** may be adjusted relative to the feed wheel **67**, so as to stop the in-feeding movement of the grinding wheel **34** when a work piece has been ground to a predetermined size.

After the stop abutment **20** has been adjusted, the knob **84** may be shifted toward the left to engage the clutch **81**, so that an in-feeding movement of the feed screw **45** may be obtained by fluid pressure actuation of the piston **75**.

When the machine is set up for a straight through grinding operation, the feed mechanism is adjusted so that when the stop abutment **20** on the feed wheel **67** is in engagement with the stop surface **21**, the grinding wheel **34** will be positioned to grind work-pieces to a predetermined size. When the parts are in this position, the clamping screw **89** is actuated to clamp the clamping ring **87** to lock the sleeve **50** against rotary motion. Any feeding movement of the grinding wheel to compensate for wheel wear may thereafter be made by means of a compensating mechanism which imparts a rotary adjustment to the feed nut **53**, as will be hereafter described.

A pair of compensating mechanisms are provided; one for imparting a compensating adjustment to the feed nut **53** during a forward compensating adjustment of the grinding wheel, and the other to impart a rearward compensating adjustment thereto. As shown in Figs. 5 and 11, a worm gear **90** surrounds the feed nut **53**, and is connected thereto by means of a roller one-way clutch **91**. A worm **92** mounted on a vertically arranged rotatable shaft **93**, meshes with the worm gear **90**. The shaft **93** is supported by a plurality of spaced anti-friction bearings **94**, **95**, and **96**. The upper end of the shaft **93** is provided with a worm gear **97** which meshes with a worm **98** mounted on a horizontally arranged shaft **99**. The shaft **99** is supported by a plurality of spaced bearings **100**, **101**, **102**, and **103** (Fig. 11).

A pawl and ratchet mechanism is provided for imparting a rotary motion to the shaft **99**. This mechanism comprises a ratchet wheel **105** mounted adjacent to the left-hand end of the shaft **99** (Fig. 11). A pivotally mounted pawl **106** is arranged to engage the teeth of the ratchet wheel **105**, and is pivotally supported by a piston **107** slidably mounted within a cylinder **108**.

A compression spring **109** serves normally to hold the piston **107** in a downward position (Fig. 8). An adjustable stop screw **110** is provided to limit the upward movement of the piston **107**, thereby determining the extent of compensating adjustment which is imparted to the feed nut **53**. When fluid under pressure is passed through a pipe **111** into a cylinder chamber **112**, the piston **107** will move upwardly until the upper surface thereof engages the stop screw **110**. During the upward movement of the piston **107**, the pawl **106** imparts a rotary motion to the ratchet wheel **105**, which serves through the mechanism previously described to impart a rotary motion to the worm gear **90** in a counter-clockwise direction. This rotary motion of the worm gear **90** serves through the roller one-way clutch to impart a counter-clockwise rotary adjustment to the feed nut **53**. A manually operable knob **113** is mounted on the left-hand end of the shaft **99** (Fig. 11).

An independent hydraulically operated mechanism is provided for imparting a rotary adjustment to the shaft **99**. This mechanism comprises a cylinder **115** (Fig. 2) which contains a slidably mounted piston **116**. The piston **116** is connected to the left-hand end of a piston rod **117**. The right-hand end of the piston rod **117** is operatively connected to a rack bar **118**. The rack bar **118** meshes with a gear **119** mounted on a rotatable shaft **120**. The shaft **120** also supports a gear **121**, which meshes with a small gear **122**. The small gear **122** is connected through a roller-type one-way clutch **123** with the shaft **99**. A stop screw **124** is provided to determine the stroke of the piston **116** and the rack bar **118**.

When fluid under pressure is passed through a pipe **125**, the piston **116** will be moved toward the right so as to impart a rotary motion to the shaft **99** is a counterclockwise direction (Fig. 12), so as to impart a compensating adjustment to the feed nut **53** in a counter-clockwise direction.

A similar feed compensating mechanism is provided for imparting a rearward compensating adjustment to the wheel slide **11** and the grinding wheel **34**. This mechanism comprises a worm gear **130** which surrounds the feed nut **53** and is connected thereto by a roller-type one-way clutch **131**. The worm gear **130** meshes with a worm **132** mounted on a vertically arranged shaft **133**, which is rotatably supported in spaced bearings **134**, **135**, and **136** (Figs. 5 and 6). The upper end of the shaft **133** is provided with a worm gear **137** which meshes with a worm **138** mounted on a rotatable shaft **139** (Figs. 5 and 7). The shaft **139** is supported in spaced bearings (not shown) and is arranged substantially parallel to the shaft **99**. The shaft **139** is provided with a ratchet wheel **141** (Figs. 7 and 8). The ratchet wheel **141** is arranged to be engaged by a pivotally mounted pawl **142** carried by a piston **143**. The piston **143** is slidably mounted within a cylinder **144**. A compression spring **145** serves normally to hold the piston **143** in a downward position. An adjustable stop screw **146** is provided to limit the upward movement of the piston **143**, thereby determining the extent of compensating adjustment imparted to the feed nut **53**.

When fluid under pressure is passed through a pipe **147** into a cylinder chamber **148**, formed at the lower end of the cylinder **144**, an upward movement of the piston **143** is obtained. During the upward movement of the piston **143**, the pawl **142** imparts a rotary motion to the ratchet wheel **141** in a counter-clockwise direction, which is transmitted through the mechanism above described to impart a rotary motion to the worm gear **130** in a clockwise direction, so as to impart a clockwise compensating adjustment to the feed nut **53**. It should be noted that the roller-type one-way clutches **91** and **131** operate in the opposite directions, so that a forward compensating adjustment is made by a counter-clockwise rotary adjustment of the worm gear **90**, and a rearward compensating adjustment is made by imparting a clockwise rotary adjustment to the worm gear **130**.

A fluid pressure system is provided to supply under-pressure for the various actuating mechanism of the machine. This system may comprise a motor-driven fluid pump **150** which draws fluid through a pipe **151** from a reservoir **152**, and passes fluid under pressure through a pipe **153**. A relief valve **154** is provided in the pressure pipe **153** to facilitate passing excess fluid under pressure directly to the reservoir **152**, so as to maintain a substantially uniform pressure within the system (Fig. 37).

A hydraulically operated mechanism is provided to facilitate moving the wheel slide **11** into a grinding position or into a truing position. This mechanism comprises a cylinder **155** which is arranged in axial alignment with the sleeve **47** and the feed screw **45**. The cylinder **155** contains a slidably mounted piston **156**, which is connected to the left-hand end of a piston rod **157**. The right-hand end of the piston rod **157** is connected to the slidably mounted sleeve **47**.

When fluid under pressure is passed through a pipe **158** (Fig. 37) into a cylinder chamber at the left-hand end of the cylinder **155**, the piston **156**, together with the feed screw **45**, the wheel slide **11**, and the grinding wheel **34**, move toward the right (Fig. 1) into a grinding position. In this position of the parts, the piston **156** is in engagement with the right-hand end of the cylinder **155**. During this movement of the piston **156**, fluid may exhaust from the cylinder chamber at the right-hand end of the cylinder **155** through a pipe **159**.

A control valve **168** is provided for controlling the admission to, and exhaust of fluid from the cylinder **155**. The valve **168** is a piston-type valve, comprising a slidably mounted valve member **169**, having a plurality of spaced valve pistons formed integrally therewith to form a plurality of valve chambers **170**, **171**, and **172**. The valve **169** is normally held in a left-hand end position by a compression spring. A solenoid S4 is provided which, when energized, serves to shift the valve **169** into a right-hand end position. In the position of the parts (Fig. 37) fluid under pressure from the pressure pipe **153** enters the valve chamber **171** and passes through the pipe **158** into the cylinder **155** to move the piston **156** toward the right into a grinding position. During this movement, fluid exhausting from the cylinder **155** through the pipe **159** enters the valve chamber **172**, passes through a central passage **205** in the valve **169**, into the valve chamber **170**, and exhausts through a pipe **206** and throttle valve **207**. By manipulation of the throttle valve **207**, the rate of movement of the piston **156** may be readily controlled as desired.

When the solenoid S4 is energized, fluid under pressure entering the valve chamber **171** passes through the pipe **159** into the right-hand end of the cylinder **155**, to move the piston **156**, together with the feed screw **45**, the wheel slide **11**, and the grinding wheel **34** toward the left (Figs. 1 and 37) into a rearward or truing position.

The rearward movement of the wheel slide continues until the left-hand end of the piston rod **157** engages an adjustable stop **160** which determines the position of the grinding wheel or a truing operation.

The stop **160** is formed integral with a screw **161** which is screw threaded in a central aperture at the end cap **162**. In order to facilitate a precise adjustment of the stop **160**, a worm gear **163** is slidably keyed onto the stop **160**. The work gear **163** meshes with a worm **164**, which is mounted on a rotatable shaft **165**. A manually operable graduated knob **166** is provided for rotating the shaft **165** and the worm **164**. An index pointer **167**, fastened to the end cap **162**, serves to facilitate positioning the graduated knob **166**. It will be readily apparent from the foregoing disclosure that a rotary motion of the knob **166** will be imparted through the worm **164** and the worm gear **163**, to rotate the screw **161** and thereby adjust the position of the stop **160**. This adjustment serves to facilitate a precise adjustment of the grinding wheel for grinding wheel truing operation to be hereafter described.

The base **10** also supports a regulating wheel **191** for controlling the rate of rotation of a work piece during a grinding operation. A regulating wheel base **175** (Figs. 12 and 14) is mounted on the base **10** and serves as a support for a transversely movable regulating wheel slide **176**. The regulating wheel base **175** is provided with a dovetailed slideway **177** which mates with a correspondingly shaped slidway formed on the under side of the slide **176**. An adjustable gib **174** (Fig. 14) is provided between the parts of the slideway **177**. The gib **174** may be adjusted by a manually operable screw **173** to take up lost motion in the slideway, and also to facilitate clamping the regulating wheel slide **176** onto the regulating wheel base **175** when desired. A pair of cylindrical end caps **179** and **180** are fixedly mounted on an upwardly extending part of the slide **176** (Figs. 1 and 14). The end caps **179** and **180** are provided with cylindrical surfaces **181** and **182** respectively which serve to pivotally support a frame **183** which carries the regulating wheel **191** as will be hereinafter described.

A clamping screw **127** passes through a clearance hole in the flanged end cap **180** (Fig. 1) and is screw threaded into the hollow frame **178**. The clamping screw **127** serves to clamp the frame **183** carrying the regulating wheel **191** to the regulating wheel slide **176**. For a straight-through grinding operation, it is desirable to skew or swivel the regulating wheel axis in a vertical plane parallel to the axis of the grinding wheel axis in order to impart a feeding component to the workpieces being ground. This is accomplished by loosening the clamping screw **127** and then actuating the adjusting screw **184** so as to swivel the frame **183** to the desired extent relative to the regulating wheel slide **176** after which the clamping screw **127** is tightened to clamp the frame **183** in adjusted position.

The frame **183** is provided with an adjusting screw **184** (Fig. 14) the end of which bears against a surface **202** formed on the regulating wheel slide **176** to facilitate tilting the frame **183** relative to the slide **176**. The frame **183** serves as a support for a plurality of spaced bearings **186**, **187** and **188** which rotatably support a regulating wheel spindle **185** (Fig. 4). The frame **183** is provided with an integral wheel guard **189** which partially surrounds the regulating wheel **191**. The regulating wheel **191** is clamped onto the spindle **185** by a pair of clamping flanges **195** and **196** which are screw threaded onto the spindle.

The variable speed transmission unit **221** is provided to facilitate rotating the spindle **185** and the regulating wheel **191** either at a relatively slow speed to control the rate of rotation of workpieces during a grinding operation, or at a relatively fast speed suitable for a wheel truing operation.

In order to facilitate mounting the regulating wheel **191** on the spindle **185**, the left hand open end of the wheel guard **189** (Fig. 4) is partially enclosed by a removable cover plate **190**. The plate **190** is provided with an internal cylindrical bore **193** which mates with an external cylindrical surface of a sleeve **194**. The sleeve **194** serves as a support for the spindle bearing **186**. When it is desired to mount a regulating wheel **191** on the spindle **185**, the cover plate **190** is detached from the wheel guard **189** and moved in an axial direction from the sleeve **194** without disturbing the spindle bearing **186**. The flange **195** is unscrewed from the spindle **185** after which the regulating wheel **191** is slid in an axial direction in position on the spindle **185**, or a worn out wheel may be romoved and replaced with a new wheel **191**.

The regulating wheel base **175** is arranged so that it may be swivelled in a horizontal plane about the axis of a pivot stud **203** (Fig. 1) which is fixedly mounted on the base **10** to facilitate adjusting the axis of the regulating wheel spindle **185** relative to the axis of the grinding wheel spindle **25**.

A downwardly projecting lub 204 is fixedly mounted on the right hand end of the regulating wheel base 175 (Fig. 1). The lug 204 projects downwardly between a pair of spaced adjusting screws 208 and 209 which are supported by the machine base 10. It will be readily apparent that by manipulation of the screws 208 and 209, the regulating wheel base 175 may be adjusted in a horizontal plane to position the axis of the regulating wheel spindle 185 into the desired relationship with the grinding wheel spindle 25, after which it may be clamped in adjusted position. The axis of spindle 185 may be positioned parallel to or at an angle to the axis of the spindle 25, as desired.

A feeding mechanism is provided for adjusting the position of the regulating wheel slide 176 relative to the base 10 and the regulating wheel base 175. This mechanism comprises a feed screw 197 rotatably supported by an anti-friction bearing 198 carried by the end cap 180. The feed screw 197 meshes with or engages a threaded aperture 200 formed in a vertically arranged bracket 201 (Fig. 1) which is fixedly mounted on the regulating wheel base 175. A feed wheel 199 is mounted on the right hand end of the feed screw 197. By manipulation of the feed wheel 199, the position of the regulating wheel slide 176 and the regulating wheel 191 may be adjusted transversely, to facilitate positioning the regulating wheel 191 into the desired relationship with the grinding wheel 34.

As shown in Fig. 2, the electric motor 35 serves to drive the grinding wheel 34 and also the regulating wheel 191 and the pumps to be hereinafter described. The pulley 37 is connected by multiple V-belt 210 with a pulley 211 mounted on a shaft 212. The shaft 212 is rotatably supported by a pair of spaced bearings 235 and 236 which are supported within a housing 237. The housing 237 is fixedly mounted on the upper end of a sleeve 213. The sleeve 213 is supported by a vertically arranged column 214 (Figs. 2 and 15). The column 214 is fixedly supported on top of a coolant pump 215 which is fixedly mounted on the base 10.

An adjusting screw 216 supported by the column 214 is provided to facilitate a vertical adjustment of the sleeve 213 so as to tension the driving belt 210. A pair of clamping screws 217 are provided on the sleeve 213 to facilitate clamping the sleeve 213 in adjusted position relative to the column 214. The shaft 212 is provided with a bevel gear 240 which meshes with a bevel gear 241 mounted on the upper end of a vertical rotatable shaft 242. The lower end of the shaft 242 is slidably keyed within a sleeve 243 which is fixedly mounted on the upper end of a drive shaft 244 of the coolant pump 215. The coolant pump 215 serves to supply coolant fluid to the work being ground and to the grinding and regulating wheels during a grinding operation, and also to supply coolant to the truing tools and wheels during a truing operation.

The shaft 212 also supports a pulley 218 which is connected by a V-belt 219 with a pulley 220 on a drive shaft 225 of a variable speed hydraulic transmission unit 221. This unit may be any of the well known commercial units, now on the marget, such as for example that manufactured by Vickers Inc. of Detroit, Michigan. The unit 221 is mounted on a platen 222 which is pivotally supported at its upper end on a rock shaft 223. An adjusting screw 224 is connected between the lower end of the platen 222 and the base 10 to facilitate swinging the unit 221 so as to tension the V-belt 219 as desired. The driven shaft of unit 221 is provided with a driven pulley 226 which is connected by a V-belt 227 with a pulley 228 mounted on a rotatable shaft 229. The shaft 229 is rotatably journaled in bearings (not shown) carried by a vertically adjustable bracket 230. The bracket 230 is supported on a horizontally adjustable bracket 231 which is adjustably supported on the regulating wheel slide 176. A pulley 232 mounted on the shaft 229 is connected by V-belts 233 with the pulley 192 on the regulating wheel spindle 185 to drive the regulating wheel 191.

The tension of the belt 233 may be adjusted by a horizontal adjustment of the bracket 231 relative to the slide 176. The tension of the belt 227 may be adjusted by a vertical adjustment of the bracket 230 relative to the bracket 231. It will be readily apparent from the foregoing disclosure that the motor 35 (Figs. 1 and 2) serves to drive the grinding wheel 34, the regulating wheel 191 and the coolant pump 215; and pump 150.

Referring now to Figs. 16, 17, 18, 19 and 20, a work guide, workrest and wheel truing apparatus have been illustrated for a straight-through grinding operation. A plate 250 (Fig. 17) is fixedly mounted on the regulating wheel slide base 175. The plate 250 supports a plate 251 which in turn supports a longitudinally extending plate 252. The plate 252 serves as a support for a longitudinally movable slide 253. Anti-friction slideways are provided between the plate 252 and the slide 253. The plate 252 is provided with a pair of spaced parallel longitudinally extending V-ways 254 and 255 (Figs. 18 and 19). The slide 253 is provided with an adjustable gib 248 having a long extending V-way 256 arranged opposite the V-way 254. The slide 253 is provided with a V-way 257 arranged opposite the V-way 255. A pair of spaced rows of balls 258 and 259 are interposed between the V-ways 254—256 and V-ways 255—257 respectively to form an anti-friction support for the slide 253. The gib 248 is provided with taper (Fig. 16) extending longitudinally to facilitate taking up lost motion between the slideway parts. An adjusting screw 249 is provided to facilitate a longitudinal adjustment of the gib 248 relative to the slide 253.

The plate 252 is arranged so that it may be swivelled in a horizontal plane about the axis of a pivot stud 251*a* which is carried by the plate 251. A clamping screw 246 (Fig. 17) passes through an elongated arcuate slot 247 and is screw threaded into the plate 252 to facilitate clamping the plate 252 in adjusted position. This swivel adjustment is provided so that the slide 253 may move in a direction parallel to the axes of the grinding wheel 34 and the regulating wheel 191, or at an angle thereto.

A work rest base 260 (Figs. 16 and 17) is fixedly mounted on the slide 253. The base 260 is provided with a longitudinally extending groove 261 to support a work rest blade 262 having an upper work supporting surface 263 which shapes downwardly toward the regulating wheel 191 (Figs. 1 and 2) for supporting work pieces during a grinding operation. The work-rest blade 262 is vertically adjustable by means of a pair of adjusting screws 265 and 266 (Fig. 17) which are screw threaded into the base 260. Lock nuts 267 and 268 are provided on the screws 265 and 266 respectively to facilitate locking the screws in adjusted position. The upwardly extending portion 260 of the work rest base 260 is provided with a plurality of spaced vertical elongated slots 269, 270, 271 and 272 (Fig. 17). A plurality of clamping screws 273, 274, 275 and 276 pass through the slots 269, 270, 271 and 272 respectively and are screw threaded into the work rest blade 262 to facilitate clamping it in adjusted position. It will be readily apparent from the foregoing disclosure that by loosening the screws 273, 274, 275 and 276 and then adjusting the screws 265 and 266, the position of the blade 262 may be adjusted vertically so as to position the axis of the work piece being ground relative to the axes of the grinding wheel 34 and the regulating wheel 191 after which the blade 262 may be clamped in adjusted position.

The work rest base 260 is arranged to swivel in a horizontal plane about the axis of a pivot stud 260*a* which is carried by the slide 253. A plurality of clamping screws 277 pass through elongated slots 278 in the work rest base 260 and are screw threaded into the slide 253 to clamp the work rest base 260 in adjusted position. This swivel adjustment is provided to facilitate adjusting

the position of the work rest 262 relative to the slide 253, and relative to the axes of the grinding wheel 34 and the regulating wheel 191.

A work guiding arrangement is provided to guide successive workpieces along the rest blade 262 to and from a grinding position. The plate 251 is provided with an upwardly extending bracket 280 (Fig. 18) which supports a horizontally adjustable bracket 281. The bracket 281 is clamped onto the bracket 280 by a pair of clamping screws 282 and 283. The clamping screws 282 and 283 pass through elongated slots 284 and 285 formed in the bracket 281 and are screw threaded into the bracket 280. The upper portion of the bracket 281 is provided with a work guiding plate 286. A vertical bracket 287 (Fig. 18) is provided with a work guiding plate 288 which is opposed to the plate 286. The bracket 287 is pivotally supported on the base 260. A horizontal hole 289 passes through the lower end of the bracket 287. A conically shaped stud 290 on the rest base 260 (Fig. 17) engages a correspondingly shaped aperture at the right hand end of hole 289. A conically shaped set screw 291 engages a correspondingly shaped left hand end portion of the hole 289. The stud 290 and set screw 291 serve as pivotal supports for the bracket 287. A compress spring 292 normally tends to move the bracket 287 in a clockwise direction (Fig. 18) to maintain a stop screw 293 in engagement with the upwardly extending portion of the rest base 260 so as to form a yielding support for the work guiding plate 288. By adjusting the stop screw 293 relative to the bracket 287, the spacing of the work guiding plates 286 and 288 may be regulated as desired to accommodate workpieces of different diameters.

A pair of vertically arranged brackets 300 and 301 are pivotally supported by a stud 302 (Figs. 17 and 19) adjacent to the other end of the workrest base 260. A pair of spaced work guide plates 303 and 304 are mounted on the brackets 300 and 301 respectively to serve as work guides to guide ground workpieces as they pass from the grinding throat between the wheels to a discharge chute (not shown). A pair of adjusting screws 305 and 306 are provided on brackets 300 and 301 respectively to facilitate adjustment of the guide plates 303 and 304 to accommodate workpieces of different diameters.

A grinding wheel truing apparatus is provided to facilitate truing the operative face of the grinding wheel 34 when desired. This apparatus comprises a truing tool 307 which mounted on a holder 308 mounted on the bracket 287. The truing tool 307 is preferably positioned to true the operative surface of the grinding wheel 34 when it is in an extreme rearward or inoperative position, that is, with the left hand end of the piston rod 157 in engagement with the adjustable stop 160.

The truing tool holder 308 is preferably adjustably and detachably mounted on the bracket 287. The holder 308 is provided with a vertically arranged dovetailed slideway 309 which mates with a corresponding shaped way on the member 287. A clamping screw 310 is provided to facilitate clamping the holder 308 to the member 287. A vertically arranged adjusting screw 311 is provided to vertically adjust the holder 208 relative to the member 287 to facilitate positioning the truing tool 307 in the desired relationship with the grinding wheel 34.

In setting up the machine and also at infrequent intervals during use, it may be desirable to true the peripheral operative surface of the regulating wheel 191. The guide plate 288 is removed from the bracket 287 by loosening a clamping plate 340. A second truing tool holder 341 is supported by a dovetail slideway 342 on the bracket 287. The holder 341 may be adjusted vertically relative to the bracket 287 by an adjusting screw 343 and may be clamped in adjusted position thereon by a clamping screw 344. A truing tool (not shown) may then be positioned in the hole 345 formed in the holder 341. The speed of the regulating wheel 191 is then increased to a suitable speed for a truing operation after which the slide 253 may be traversed longitudinally to traverse the truing tool across the peripheral face thereof to true the same. The regulating wheel 191 may be advanced toward the truing by actuation of the feed wheel 199 to facilitate truing the desired amount from the peripheral surface thereof. The truing tool for the regulating wheel is identical with the truing tool 307 but must be removed from the supporting hole 345 in the holder 341 during grinding.

In a straight-through grinding operation, it may be desirable to provide a slight taper 346 on the periphery of the grinding wheel 34 adjacent to the work entrance position (Fig. 20). This is preferably accomplished by providing a template or forming bar 347 which is adjustably mounted on the upper surface of the bracket 287. The bar 347 is pivotally supported by a vertical pivot screw 348 supported on the bracket 287. A clamping screw 349 passes through a clearance hole in the bar 347 and is screw threaded into the bracket 287 to facilitate clamping the bar 347 in adjusted position on the bracket 287. An adjustable screw 350 mounted on top of the bracket 281 serves as a follower along which the bar 347 traverses. The bar 347 traversing across the fixed follower screw 350 imparts a swinging movement to the bracket 287 as it is traversed along so as to impart a controlled transverse movement to the truing tool 307. The bar 347 is swivelled to the desired extent and screws 293 and follower screw 350 adjusted so that during the initial traversing movement of the truing tool 307, the bar 347 imparts a transverse movement to truing tool 307 to true a taper face 346 on a grinding wheel. This continues until the stop screw 293 engages surface 294 to hold truing tool 307 against further transverse movement after which continued longitudinal traversing movement of the truing tool 307 trues a cylindrical face 346*a* on the remainder of the operative face of the grinding wheel 34 (Fig. 20). In case a taper face 346 is not desired, the follower screw 350 may be adjusted relative to the bracket 281 so that its end face is out of engagement with the bar 347.

A traversing mechanism is provided for the slide 253 to facilitate traversing the truing tool 307 or the regulating truing tool across the operative face of the grinding wheel 34. This mechanism comprises a cylinder 315 fixedly mounted relative to slide plate 252. The cylinder 315 contains a slidable piston 316 which is connected to the left hand end of a piston rod 317 (Figs. 17 and 37). The right hand end of the piston rod 317 is fixedly connected to the right hand end of the slide 253.

When fluid under pressure is passed through the pipe 318 into a cylinder chamber 319, the piston 316 together with the slide 253 are moved toward the right to traverse the truing tool 307 toward the right across the face of the grinding wheel 34 to true the same. During this movement fluid within a cylinder chamber 320 may exhaust through a pipe 321. A throttle valve 322 and a ball check valve 323 are provided in the pipe line 318. A throttle valve 324 is provided in the pipe line 321. These valves serve to control the rate of the traversing movement of the slide 253 and the truing tool 307.

A control valve 325 is provided for controlling the admission to and exhaust of fluid from the cylinder 315 and also the feed compensating cylinder 115. The valve 325 is a piston-type valve having a slidably mounted valve member 326. A plurality of spaced valve pistons are formed integral with the valve member 326 to form a plurality of spaced valve chambers 327, 328 and 329. The member 326 is also provided with a central passage 330 which connects the valve chamber 327 with the valve chamber 329. A compression spring 331 is provided normally to hold the valve member 326 in a left hand end position. A solenoid S5 is provided which when energized serves to shift the valve member 326 into a right hand end position. In the position of the valve 325 (Fig. 37), fluid under pressure from the pressure pipe 153 enters the valve chamber 328 and passes through the pipe 321, through the throttle valve 324 into the cylinder

chamber 320 to move the piston 316 into a left hand end position at a rate controlled by the throttle valve 322. Fluid also passes from the valve chamber 328, through the pipe 126 into the right hand end of the cylinder 115 to move the piston 116 into a left hand end position. During admission of fluid to the cylinder chamber 320, the slide 253 is traversed toward the left to traverse the truing tool 307 across the operative face of the grinding wheel 34.

When the solenoid S5 is energized to shift the valve 325 into a right hand end position, fluid under pressure is passed through the pipe 318 to move the piston 316 together with the slide 253 toward the right to traverse the truing tool across the face of the grinding wheel 34. Fluid under pressure is also passed through the pipe 125 into the left hand end of the cylinder 115 to move the piston 116 toward the right so as to impart a compensating feed adjustment to the grinding wheel 34. The control valve 325 is actuated automatically in a manner to be hereinafter described to control the truing of the grinding wheel 34.

Referring now to Figs. 21, 22 and 23, a slightly different arrangement of the regulating wheel slide and the truing tool slide has been illustrated, to adapt the machine for a plunge-cut operation. Instead of supporting the work rest and truing apparatus directly on the regulating wheel slide, they are mounted on an independent slide to facilitate a transverse movement for truing a predetermined shape or form on the periphery of not only the regulating wheel but also the grinding wheel. As illustrated in Fig. 22, a plate 360 is mounted on top of the regulating wheel base 175. The plate 360 is provided with spaced V-ways 361 and 362 which are arranged parallel to the dovetail headway 177. A slide 363 is similarly provided with spaced V-ways 364 and 365. A pair of rows of balls 366 and 367 are arranged between the V-ways 361—364 and 362—365 to form an antifriction support for the slide 363. The V-way 364 is preferably formed on the side face of a tapered gib 368 by means of which the slide parts may be readily adjusted to take up backlash in the slide parts.

The forward end of the slide 363 is provided with a plate 370 which extends in a direction substantially parallel to the axes of the grinding wheel 34 and the regulating wheel 191. The plate 370 is arranged so that it may be swivelled about the axis of a vertical pivot stud 370*a* in a horizontal plane. A clamping screw 355 passes through an elongated arcuate slot 356 formed in the slide 363 and is screwed threaded into the plate 370. The clamping screw 355 serves to facilitate clamping the plate 370 in the desired adjusted position.

As shown in Fig. 23, the plate 370 is the support for a horizontal movable slide 373 which is the same as that described in connection with the straight-through grinding set-up. The plate 370 is provided with spaced V-ways 371 and 372. The slide 373 is similarly provided with spaced V-ways 374 and 375. A pair of rows of balls 376 and 377 are interposed between the V-ways 371—374 and 372—375 to form an anti-friction support for the slide 373. The V-way 374 is preferably formed in a tapered gib 378 which is adjustably longitudinal relative to the slide 373 to facilitate taking up backlash in the slideway apparatus.

The slide 373 supports a work rest base 380 having a longitudinally extending groove 381 which supports a work rest blade 382 having a pivotal work supporting surface 383 formed thereon and to facilitate clamping the work rest base in adjusted position on the slide 373, a plurality of clamping screws 357 are provided which pass through elongated slots 358 (Fig. 21) formed in the said rest base 380. A pair of vertically mounted adjusting screws 384 and 385 are provided to facilitate a vertical adjustment of the work rest blade 382 relative to the work rest base 380. A pair of lock nuts 386 and 387 are provided to facilitate locking the adjusting screws 384 and 385 in adjusted positions. One of the upwardly extended portions of the work rest base 380 is provided with a plurality of spaced elongated slots 388, 389, 390 and 391. A plurality of clamping screws 392, 393, 394 and 395 pass through the elongated slots 388, 389, 390 and 391 respectively and are screw threaded into the work rest blade 382 to facilitate clamping the blade in adjusted position relative to the work rest base 380.

The work rest base 380 is preferably supported by vertical pivot stud 380*a* on the slide 373 to facilitate swivelling the work rest base 380 in a horizontal plane to position the work rest blade 382 in the desired relationship with the grinding wheel 34 and the regulating wheel 191.

A truing apparatus is provided on the slide 373 which is somewhat similar to that previously described except that it is arranged for form truing, as will be hereinafter described. As shown in Fig. 23, a vertically arranged bracket 400 is pivotally supported by a pivot stud 401 and a pivot screw 402 (Fig. 22). An adjusting screw 403 is screw threaded through the bracket 400 and bears against a vertically arranged surface 404 of the work rest base 380. The upper end of the bracket 400 supports a truing tool 405. A vertically arranged adjusting screw 398 is screw threaded through a horizontally extending portion of the bracket 400 to facilitate adjusting the bracket 400 to maintain the stop screw 403 in engagement with the surface 404 work rest base. A lock nut 399 is provided to facilitate locking the adjusting screw 398 in adjusted position. The truing tool 405 is mounted in a holder 406 which is removably attached to the bracket 400 by dovetail slideway 407. A clamping screw 408 (Fig. 21) is provided to facilitate clamping the holder 406 on the bracket 400. A vertically arranged adjusting screw 409 is provided to facilitate adjusting the holder 406 relative to the bracket 400.

The bracket 400 is provided with a regulating wheel truing tool 410 which is supported by a detachable holder 411. A dovetail slideway 412 is provided between the holder 411 (Fig. 21) and the bracket 400. A clamping screw 413 is provided to clamp the holder 411 on to the bracket 400. A vertically arranged adjusting screw 414 (Fig. 22) is provided to facilitate adjusting the holder 411 vertically relative to the bracket 400.

In a plunge-cut grinding operation it is necessary to utilize predetermined forms or shapes on the peripheries of not only the grinding wheel but also the regulating wheel. A formed truing arrangement has been illustrated in Figs. 21 and 22 comprising a pair of spaced brackets 420 and 421 which are fixedly supported on the regulating wheel slide base 175. The brackets 420 and 421 serve as supports for a pair of horizontally arranged forming bars, a forming bar 422 for controlling the shape of the grinding wheel and a forming bar 423 for determining the shape of the regulating wheel.

A clamping and feed screw 424 passes through an elongated slot 425 formed in the forming bars 422–423 and is screw threaded into the bracket 421. A clamping screw 426 passes through elongated slots 427 formed in the other ends of the forming bars 422–423 and is screw threaded into the bracket 420. It will be readily apparent from the foregoing disclosure that by manipulation of the clamping screws 424 and 426 the forming bars 422 and 423 may be adjusted longitudinally and swivelled to a slight extent at their lefthand ends (Fig. 21) due to clearance between the clamping screw 426 and the elongated slots 427.

In order to facilitate a slight swivel adjustment of the forming bars, a bracket 428 (Figs. 21 and 23) is mounted on the bracket 420 and is provided with a pair of upwardly extending lugs 429 and 430 which carry a pair of opposed adjustment screws 431 and 432 respectively to facilitate adjusting the forming bar 423 in a horizontal plane, and an adjusting screw 433 for importing a similar horizontal adjustment to the forming bar 423.

The bracket 421 (Fig. 21) is provided with an upwardly extended lug 434 which is provided with a pair of longi-

tudinally extending adjusting screws 435 (only one of which has been illustrated in Fig. 21). By manipulation of the adjusting screws 435, the forming bars 422 and 423 may be adjusted longitudinally relative to the supporting brackets 420–421.

The forming bars 422 and 423 are utilized to impart a transverse movement to the slide 363 during a longitudinal movement of the slide 373. As illustrated in Fig. 21, a follower block 440 is pivotally supported by a stud 441 which is mounted on the longitudinal movement slide 373. The follower block 440 is provided with a projecting follower 442 which is arranged to slide along the forming bar 422. The follower block 440 is provided with a stop surface 443 which engages a surface 444 on the work rest base 380. The forming bar 422 together with the follower projection 442 serves to facilitate generating a predetermined shape on the grinding wheel 34.

When it is desired to true a predetermined shape on the regulating wheel 191, the follower block 440 is rocked in a clockwise direction so that stop surface 445 engages a surface 447 on the work rest base 380. In this position of the parts, the follower projection 442 moves out of engagement with the forming bar 422 and a follower projection 446 moves into operative engagement with the forming bar 423.

A yieldable means is provided for maintaining the followers in operative engagement with the forming bars during a wheel truing operation. A tension spring 450 is connected between a stud 451 on the slide 363 and a stud 452 on the regulating wheel base 175. A tension spring 453 is connected between a stud 454 on the slide 363 and a stud 455 on the regulating wheel base 175. The tension of the springs 450 and 453 tends to move the slide 363 toward the right (Fig. 23) relative to the regulating wheel base 175 so as to maintain either the follower 442 in operative engagement with the forming bar 422 during a grinding wheel truing operation, or the follower 446 in operative engagement with the forming bar 422 during a regulating wheel truing operation.

The slide 373 supporting the workrest blade 382 and the truing tools 405 and 410 is traversed longitudinally by the same fluid pressure operated piston and cylinder mechanism as previously described in connection with the straight-through grinding operation.

The grinding wheel 34 is trued with the follower 440 positioned as shown in full lines in Fig. 21 with the follower point 442 in operative engagement with the template or forming bar 422. With the parts in this position, a longitudinal traversing movement of the slide 373 traverses the truing tool 405 across the operative face of the grinding wheel 34. During this movement, the forming bar imparts a controlled traverse movement to the truing tool to generate a predetermined shape thereon. The grinding wheel 34 is always trued with the wheel slide in a rearward or inoperative position with the lefthand end of the piston rod 157 in engagement with the stop 160 (Fig. 1).

The plate 370 is arranged to swivel in a horizontal plane about the axis of a pivot stud 370*a* which is carried by the slide 363. A clamping screw 355 passes through an elongated arcuate slot 356 and is screw threaded into the plate 370 (Fig. 22) to facilitate clamping the plate 370 in adjusted position relative to the slide 363. This adjustment is provided to facilitate adjusting the path of movement of the truing tool and work rest slide 373 so that it travels in a direction parallel to the axes of the grinding wheel 34 and the regulating wheel 191, or at an angle thereto.

The work rest base 380 (Fig. 22) is arranged so that it may be swivelled in a horizontal plane about the axis of a pivot stud 380*a* carried by the slide 373. A plurality of clamping screws 357 (Fig. 21) pass through the elongated arcuate slots 358 formed in the work rest base 380 and are screw threaded into the slide 373 to facilitate clamping the work rest base in adjusted position thereon. This swivel adjustment is provided so that the work rest 382 may be adjusted so that it is parallel to the path of movement of the slide 373 and also parallel to the axes of the grinding wheel 34 and the regulating wheel 191, or so that it may be angularly positioned thereto.

At infrequent intervals, such as, when setting-up the machine or after a new regulating wheel 191 has been installed, it is necessary to true the operative face of the regulating wheel 191. The follower block 440 is manually swung in a clockwise direction (Fig. 21) into the broken line position 440, to position the follower point 446 into operative engagement with the forming bar 423 which serves driving a longitudinal traversing movement of the slide 373 to impart a transverse movement to the truing tool 410 so as to generate a predetermined contour on the operative face of the regulating wheel 191. The regulating wheel 191 may be advanced toward the truing tool 410 by manual actuation of the feed wheel 199 to facilitate truing a predetermined amount from the operative face thereof. Before truing the regulating wheel 191, the speed of the wheel is increased to a suitable truing speed.

A modified driving arrangement has been illustrated in Figs. 24, 25, 26 and 27. The motor 35 through V-belts 38 imparts a rotary motion to the pulley 39 and the wheel spindle 25 to rotate the grinding wheel 34 at a suitable grinding speed. The pulley 39 is connected by V-belt 460 (Fig. 24) with an idler pulley 461 which is rotatably supported on a shaft 462 carried by a bracket 463. A clamping screw 464 passes through an elongated slot 465 in the bracket 46 and is screw threaded into the base 10 to facilitate a vertical adjustment of the bracket 463 and idler pulley 461 to tension the driving belts 460. The pulley 461 is connected by V-belts 466 (Fig. 24) with a pulley 467 (Fig. 25) which is mounted on a rotatable shaft 468. The shaft 468 is provided with a bevel gear 469 which meshes with a bevel gear 470 mounted on the upper end of a vertical shaft 471. The shaft 471 is provided with a worm 472 which meshes with a worm gear 473 mounted on a horizontal shaft 474.

A variable speed driving mechanism is provided between the shaft 474 and the regulating wheel spindle 185 to facilitate driving the regulating wheel 191 at a variable relatively slow speed for controlling rotation of the work during a grinding operation. A variable speed pulley 475 is mounted on the shaft 474. The pulley 475 may be of any of the wellknown opposed cone pulleys, such as for example the "Roto-Cone" variable speed pulley manufactured by the Gerbing Manufacturing Company of Northbrook, Illinois, which are covered by United States patents to W. E. Gerbing, Nos. 2,475,954 and 2,475,955 dated July 12, 1949, to which reference may be had for details of disclosure not contained herein. The pulley 475 consists of a pair of opposed slidably mounted frusto-conical members 475*a* and 475*b* which are normally urged away from each other by a compression spring 476 (Figs. 25 and 27). A thrust rod 477 which is actuated by a manually operable screw 479 is provided to facilitate adjusting the pulley members 475*a* and 475*b* relatively toward and from each other against the compression of the spring 476 to vary the effective diameter of the pulley 475.

The pulley 475 is connected by a driving belt 480 with a similar variable speed pulley 481. The pulley 481 comprises a pair of opposed slidably mounted frusto-conical members 481*a* and 481*b* (Figs. 25 and 26) which are urged toward each other by a compression spring 484. The pulley members 481*a* and 481*b* are slidably keyed on a sleeve 485 (Fig. 26). The sleeve 485 is fixedly keyed on a rotatable sleeve 486 which is rotatably journalled in bearings 487 and 489 with the sleeves 485 and 488. A slidably mounted clutch member 491 is slidably keyed on the shaft. When in a lefthand end position, clutch teeth on the lefthand end of member 491 engage teeth of a clutch member 492 formed integral with the sleeve 488. A yoked member 494 is mounted

on a rock shaft 495. An actuating lever 496 is fixedly mounted on the end of the shaft 495. A slide rod 497 slidably supported in the frame 183 (Fig. 25) is connected at its right hand end to the upper end of the lever 496. The lefthand end of the rod 497 is provided with an actuating knob 498 to facilitate actuation of the clutch 491 from the front of the machine.

A pulley 500 is keyed onto the righthand end of the shaft 490. The pulley 500 is connected by multiple V-belts 501 with the pulley 192 on the regulating wheel spindle 185. The variable speed drive above described serves to rotate the spindle 185 and the regulating wheel 191 at a variable relatively slow speed for controlling work rotation during a grinding operation.

A high speed drive for the regulating wheel 191 is provided to facilitate rotating it at a relatively high speed during a wheel truing operation. A pulley 515 (Fig. 25) is mounted on the shaft 468. The pulley 515 is connected by multiple V-belts 516 with a pulley 517 connected through a friction clutch 518, the other part of which is keyed to the sleeve 488 (Fig. 26). When the clutch member 491 is shifted toward the right into engagement with the clutch member 493, the drive mechanism just described serves to rotate the regulating wheel 191 at a predetermined truing speed.

In order to facilitate tensioning the V-belts 501 and 516, the housing is adjustably mounted. The housing 505 is provided with a downwardly extending integral bracket 506. A pair of clamping screws 507 and 508 pass through elongated slots 509 and 510, respectively, and are screw threaded into a vertical face on a horizontally adjustable bracket 511 which is adjustably mounted on the regulating wheel slide 176. It will be readily apparent from the foregoing disclosure that a horizontal adjustment of the bracket relative to the regulating wheel slide 176 serves to facilitate adjusting the tension of the V-belts 501 and a vertical adjustment of the bracket 506 relative to the bracket 511 serves to facilitate adjusting the tension of the V-belts 516.

A housing 518 (Fig. 25) supporting the shafts 468 and 474 is supported on the upper end of a hollow column 519 which is in turn supported by a coolant supply pump 520. The pump 520 is supported by a bracket 521 which is fastened to the base 10 and is driven by a shaft 522. A lubricant supply pump 523 is mounted on the housing 518 and is driven by the shaft 468. The pump 523 may be connected to supply lubricant to the grinding wheel and the regulating wheel spindle bearings (not shown). A fluid pressure pump 524, for supplying fluid under pressure for the actuating mechanisms of the machine, is mounted on top of the housing 518. The pump 524 is provided with a drive shaft 525 having a bevel gear 526 which meshes with the bevel gear 469. It will be readily apparent from the foregoing disclosure that the electric motor 35 serves not only to drive the grinding wheel 34 and regulating wheel 191 but also the pumps of the machine. As shown in Figs. 1 and 2, a hydraulic variable speed driving unit 220 may be utilized for imparting a variable speed to the regulating wheel 191. In the preferred construction, as shown in Figs. 24, 25, 26 and 27 a belt-driven arrangement is provided including a variable speed cone pulley drive for imparting a variable speed to the regulating wheel to control work rotation during a grinding operation, and a belt drive for imparting a relatively fast speed to the regulating wheel during a wheel truing operation.

Referring now to Fig. 37, a solenoid-actuated control valve 530 is provided to control the admission to and exhaust the fluid from the wheel feed cylinder 74. The control valve 530 is a piston-type valve comprising a slidably mounted valve member 531 having a plurality of valve pistons forming integrally therewith to form a plurality of valve chambers 532, 533 and 534. The valve member 531 is also provided with a central passage 535 which connects the valve chamber 532 with the valve chamber 534.

The valve member 531 is arranged to be shifted longitudinally by fluid under pressure admitted to and exhausted from opposite end chambers 536 and 537 forming at the opposite ends of the valve 530. A pilot valve 538 is provided for controlling the shifting movement of the valve member 531. The pilot valve 538 comprises a valve stem 539 having a plurality of valve pistons formed integrally therewith to form a pair of spaced valve chambers 540 and 541. The valve 538 is provided with a central passage 542 which inter-connects the valve chamber 540 with an end chamber 543. A compression spring 544 serves normally to hold the valve stem 539 in a righthand end position. A solenoid S1 which when energised serves to shift the valve stem toward the left into a reverse position. As illustrated in Fig. 37, fluid under pressure passing through the pressure pipe 153 enters the valve chamber 533 and passes through a pipe 545, through a ball check valve 546 into a cylinder chamber 547 formed at the righthand end of the cylinder 74 so as to move the piston 75 into a lefthand end position. During this movement fluid within a cylinder chamber 548 may exhaust through the pipe 85, through a throttle valve 549 into the valve chamber 534, through the central passage 535, into the valve chamber 532 and exhausts through a pipe 550 into the reservoir 152.

When fluid under pressure is passed into the valve chamber 533, it may also pass through a passage 551 into the pilot valve chamber 541 and pass through a passage 552 into the end chamber 537 to shift the valve member 531 into a lefthand end position, as illustrated in Fig. 37.

When it is desired to start an in-feeding movement of the grinding wheel the solenoid S1 is energized to shift the pilot valve stem 539 toward the left so that fluid under pressure entering the pilot valve chamber 541 passes through a passage 553 into the end chamber 536 so as to shift the valve member 531 toward the right into a reverse position to reverse the flow of fluid under pressure to the feed cylinder 74. When the valve member 531 is in a right-hand end position, fluid under pressure entering the valve chamber 533 passes through the throttle valve 549, through the pipe 85 into the cylinder chamber 548 to move the piston 75 toward the right thereby actuating the wheel feeding mechanism above described to cause the grinding wheel 34 to move into operative grinding engagement with the work piece being ground. During this movement fluid within the cylinder chamber 547 may exhaust through the pipe 86.

It is desirable to provide means to rapidly take up the gap between the grinding and regulating wheels during the initial portion of the infeeding movement. This is preferably accomplished by means of a shuttle-type valve 560 comprising a slidably mounted valve piston 561 having a pair of spaced valve pistons forming integrally therewith to form a valve chamber 562. When fluid under pressure is passed through the pipe 85 to initiate a feeding movement of the piston 75, fluid under pressure passes through a pipe 563 into a left-hand end chamber in the valve 560 to move the valve member 561 toward the right. During this movement fluid within a right hand end chamber 564 may exhaust through a pipe 565 and through a throttle valve 566 which determines the rate of movement of the valve member 561 toward the right fluid under pressure exhausting through the pipe 86 may enter the valve chamber 562 as the chamber passes over the port at the end of the pipe 86 to allow a predetermined metered exhaust of fluid through an exhaust pipe 567. It will be readily apparent from the foregoing disclosure that by varying the aperture in the throttle valve 566, the speed of movement of the valve member 561 may be adjusted so that a predetermined amount of fluid may exhaust through the exhaust pipe 567.

The rapid unrestricted exhaust of fluid from the cylin-

der chamber 547 in the feed cylinder 74 (Fig. 37), through the chamber 562 in the valve 560, and the exhaust pipe 567 allows a rapid take-up of backlash in the parts of the wheel feeding mechanism. A ball check valve 568 is provided in the pipe 565 so that when the flow of fluid is passed through the pipe 45 it may flow substantially unrestricted into the end chamber 564 of the valve 560 to return the valve member 561 into a left hand end position. A throttle valve 569 is provided in the pipe 86, so that after the chamber 562 passes over the port at the end of the pipe 86, fluid exhausting from the cylinder chamber 547 thereafter passes through the throttle valve 569 which serves to control the rate of the infeeding movement of the grinding wheel 34.

A control valve 575 is provided for controlling the admission to and exhaust of fluid from the compensating cylinders 108 and 144. The valve 575 is a piston-type valve comprising a slidably mounted valve member 576 which is provided with a plurality of spaced valve pistons to form spaced valve chambers 577, 578 and 579. The valve member 576 is provided with a central passage 580 to connect the valve chamber 577 with the valve chamber 579. The valve member 576 is normally held in a central position by a pair of compression springs 581 and 582. An electric solenoid S3*a* is provided which when energized serves to shift the valve member 576 toward the left. Similarly a solenoid 83*b* is provided which when energized serves to shift the valve member 576 toward the right. Fluid under pressure from the pipe 153 passes into the valve chamber 578. When the solenoid S3*b* is energized, fluid under pressure from the chamber 578 passes through the pipe 111 into the cylinder 108 to impart a forward compensating feed to the grinding wheel 34. Similarly when solenoid S3*a* is energized, fluid from the chamber 578 passes through the pipe 147 into the cylinder 144 to impart a rearward compensating feed to the grinding wheel 34. When the valve 575 is in a central position as illustrated in Fig. 28, fluid from both the compensating cylinders 108 and 144 may exhaust through the valve 575 and exhaust through a pipe 584 into the reservoir 152. The operation of the valve 575 will be more fully described hereinafter.

As illustrated in Fig. 37, when the grinding machine is set up for a plunge-cut grinding operation, a work magazine or hopper 590 is provided to hold a plurality of work pieces 591 to be ground and to successively feed the work pieces on to the work rest 382 for a grinding operation. A pair of rock arms 592 and 593 are pivotally supported on studs 594 and 595. The rock arms 592 and 593 are provided with projecting lugs 596 and 597 which in the positions illustrated engage the periphery of the lower work pieces 591 to prevent it dropping on to the work rest 382. A lever 598 is pivotally connected to the upper end of the rock arm 592 by a stud 599. Similarly a lever 600 is connected by a stud 601 with the rock arm 593. The inner ends of the levers 598 and 600 are connected by a stud 602 with the lower end of a piston rod 603. The piston rod 603 is connected to a piston 604 contained within a cylinder 605.

When fluid under pressure is passed through a pipe 606 into the lower end of the cylinder 605, the piston 604 is moved upwardly thereby swinging the levers 598 and 600 so as to rock the arms 592 and 593 to withdraw the lugs 596 and 597 so that the lower work piece may drop on to the work rest blade 382. During this movement a lug 607 on the rock arm 592 and a lug 608 on the rock arm 593 move inwardly to hold the next work piece against downward movement. During the upward movement of the piston 604 fluid within the upper end of the cylinder 605 may exhaust through a pipe 609. It will be readily apparent from the foregoing disclosure that the lugs 596—597 and the lugs 607—608 together with the rock arms 592 and 593 serve as an escapement mechanism to govern the flow of work pieces from the hopper 590 on the work rest 382.

A control valve 610 is provided for controlling the admisison to and exhaust of fluid from the cylinder 605. The valve 610 is provided with a slidably mounted valve member 611 having a plurality of spaced valve pistons formed integrally therewith to form spaced valve chambers 612, 613 and 614. The valve member 611 is provided with a central passage 615 which interconnects the valve chamber 612 with the valve chamber 614. A compression spring 616 is provided normally to hold the valve member 611 in a left hand end position. A solenoid S6 is provided which when energized serves to shift the valve member 611 into a right hand end position. In the position of the valve 610 (Fig. 37) fluid under pressure from the pipe 153 enters the valve chamber 613 and passes through the pipe 609 to hold the piston 604 in a downward position. During the downward movement of the piston, fluid may exhaust from the lower end of the cylinder 605 through the pipe 606 into the valve chamber 614, through the passage 615, into the valve chamber 612 and exhaust through a pipe 617 and a throttle valve 618 into the reservoir 152. It will be readily apparent that the rate of movement of the piston 604 may be readily controlled by adjustment of the throttle valve 618.

When it is desired to release a new work piece 591 from the hopper 590 on to the work rest 382, the solenoid S6 is energized to shift the valve member 611 toward the right so that fluid under pressure entering the valve chamber 613 passes through the pipe 606 into the lower end of the cylinder 605 to cause an upward movement of the piston 604. The upward movement of the piston 604 rocks the arms 592—593 to release the lower work piece 591 so that it may drop into engagement with the work piece 382.

Work pieces 591 are successively deposited on the work rest 382 after which the grinding wheel is given a plunge-cut feed to grind the work pieces to a predetermined size after which the grinding wheel retracts to an inoperative position. A work discharge mechanism is provided for sliding the ground work pieces axially from the work rest 382 into a V-shaped trough 623 and into a V-shaped discharge chute 664. This mechanism preferably comprises a work ejector rod 625 which serves as a piston rod and is operatively connected to a piston 626. The piston 626 is slidably mounted within a cylinder 627 which is supported on a base 628. The base 628 is clamped in an operating position by means of a pair of clamping screws 629 and 630. An adjustable stop screw 631 is provided to limit the movement of the ejector rod toward the right.

A control valve 632 is provided for controlling the admission to and exhaust of fluid from the cylinder 627. The valve 632 is provided with a slidable valve member 633 having a plurality of spaced valve pistons formed integrally therewith so as to form spaced valve chambers 634, 635 and 636. The valve member 633 is also provided with a central passage 637 which inter-connects the valve chamber 634 with the valve chamber 636. A compression spring 638 serves normally to hold the valve member 633 in a left hand end position. A solenoid S2 is provided which serves when energized to shift the valve member 633 into a right hand end position.

In the position of the valve 632 (Fig. 37) fluid under pressure from the pipe 153 entering the valve chamber 635 passes through a pipe 639, through a throttle valve 640 into a cylinder chamber 641 formed at the right hand end of the cylinder 627 to move the piston 626 together with the ejector rod 625 toward the right into the position illustrated in Fig. 37. During this movement fluid within a cylinder chamber 642 formed at the left hand end of the cylinder 627 may exhaust through a pipe 643, through a throttle valve 644, into the valve chamber 636, through the central passage 637 into the valve chamber 634 and exhausts through a pipe 645 into the reservoir 152. When the solenoid S2 is energised

the flow of fluid under pressure from the control valve 632 is reversed so that fluid under pressure passes through the pipe 643 into the cylinder chamber 642 to move the piston 626 together with the ejector rod 625 toward the right so as to draw it to an inoperative position. It will be readily apparent from the foregoing disclosure that by manipulation of the throttle valve 640 and 644 the rate of movement of the ejector rod 625 may be varied as desired.

A work gauging mechanism is provided for automatically checking the size of work pieces as they pass through the V-shaped trough 623. This mechanism comprises a gauge 650 which is movable in a vertical direction toward and from an operative position. As illustrated in Fig. 37 a vertical section has been illustrated through the gauge 650 and the V-shaped trough 623. These parts have been illustrated in a position at right angles to the normal position diametrically to show operation. The gauge 650 is provided with a V-shaped work engaging surface 651 together with an actuating plunger 652 of a limit switch LS1.

A hydraulically operated mechanism is provided for moving the gauge 650 to and from an operating position. This mechanism comprises a cylinder 653 which contains a slidably mounted piston 654 formed at the lower end of piston rod 655. The upper end of the piston rod 655 is connected by a stud 656 with a rock arm 657. The rock arm 657 is pivotally supported by a stud 658 carried by a bracket 659. The other end of the rock arm 657 is connected by a stud 660 with the upper portion of the gauge 650.

As illustrated in Fig. 37, the control valve 632 serves not only to control the admission to and exhaust of fluid from the work ejector cylinder 627, but also to control the admission to and exhaust of fluid from the gauge actuating cylinder 653.

In the position of the valve 632 fluid under pressure from the valve chamber 635 passing through the pipe 639 passes through a throttle valve 661 and a pipe 662 into the upper end of the cylinder 653 to move the piston 654 downwardly into an inoperative position so as to raise the gauge 650 also into an inoperative position. During this movement fluid may exhaust from the lower end of the cylinder 653, into the pipe 643, into the valve chamber 636, through the central passage 637 into the valve chamber 634 and through the exhaust pipe 645 into the reservoir 152.

Similarly when the solenoid S2 is energized to reverse the flow of fluid, fluid under pressure passes through the pipe 643, into the lower end of the cylinder 653 thereby causing an upward movement of the piston 654. The upward movement of piston 654 serves to rock the rock arm 657 in a clockwise direction thereby moving the gauge 650 downwardly into engagement with a work piece 591. If the work piece is of a predetermined size, the actuating plunger 652 will be moved upwardly so that both sides of contact of limit switch LS1 are opened when the V-shaped surface 651 engages the ground work piece. A ball check valve 663 is provided between the pipe 639 and pipe 662 to allow the unrestricted flow of fluid to the upper end of the cylinder 653 to facilitate a rapid movement of the gauge 650 to an upper or inoperative position.

It may be desirable to provide a truing apparatus in which an independent truing tool is provided for truing the grinding wheel 34 and the regulating wheel 191 respectively. As shown in Fig. 28, the bracket 400 which supports the truing tool 405 is pivotally mounted on a stud 670 supported by the work rest base 380. The stop screw 403 carried by the bracket 400 bears against a stop surface 404. An adjusting screw 398 is provided for adjusting the position of the bracket 400 so as to maintain the stop screw 403 in operative engagement with the surface 404. The truing tool 405 serves during a longitudinal movement of the slide 373 to true the operation face of the grinding wheel 34.

The stud 670 also serves as a pivotal support for a bracket 671. The bracket 671 is provided with a vertically arranged cylindrical aperture 672 which supports a vertically arranged truing tool post 673. The post 673 supports a stop screw 674 which engages a stop surface 675 formed on the work rest base 380. An adjusting screw 676 carried by the bracket 671 serves to facilitate maintaining the stop screw 674 in engagement with the stop surface 675. The lower portion of the post 673 is screw threaded and provided with a pair of nuts 677 which serve to vertically adjust the position of the post 673. An upwardly extending boss on the bracket 671 is provided with a vertical slot 678 and a clamping screw 679 to facilitate clamping the post 673 in adjusted position. The upper end of the post 673 supports a block 680 which carries a truing tool 681 for truing the operative face of the regulating wheel 191. It will be readily apparent from the foregoing disclosure that by adjustment in the stop screw 403, the position of tse truing tool 405 may be adjusted into the desired position in setting up the machine. Similarly by vertically adjusting the post 673 by manipulation of the nuts 677, the truing tool 681 may be vertically adjusted. By manipulation of the stop screw 674, the truing tool 681 may be adjusted in a transversing direction.

In the grinding of shouldered work pieces, it is desirable to grind not only the cylindrical portion of the work piece but also the shoulder face adjacent thereto. This is preferably accomplished by angularly positioning the work rest. It is desirable to provide a truing apparatus for truing not only the peripheral face of the grinding wheel 34 but also a frusto-conical face 688 on the side face thereof to facilitate a shoulder grinding operation. (Figs. 29, 30 and 31).

A modified form of truing apparatus has been illustrated in Fig. 29 in which the pivotally mounted bracket 400 supporting the truing tool 405 is provided with a horizontally extended arm 685. An adjusting screw 684 serves to facilitate adjusting the position of the bracket 400 relative to the work rest base 380. A compression spring 686 (Fig. 29) serves to maintain the screw 684 in operative engagement with the upper surface of the slide 373. The upper end of tse bracket 400 supports a truing tool 687 (Fig. 30) for truing the frusto-conical face 688 on the grinding wheel 34. A cam actuated mechanism is provided for imparting a rocking movement to the bracket 400 to swing the truing tool 687 to true the frusto-conical face 688. This mechanism comprises a cam 689 mounted on a rock shaft 690. The rock shaft 690 is rotatably supported by the work rest base 380. The cam 689 rides on a plane surface 691 formed on the upper surface of the arm 689. A manually operable lever 692 is fixedly mounted on the rock shaft 690 so that when the lever 692 is moved in a clockwise direction into broken line position 692*a* (Fig. 29) the truing tool 687 will be traversed across the frusto-conical face 688 (Fig. 30) of the grinding wheel 34 to true the same.

A modified arrangement for truing the frusto-conical face 688 of the grinding wheel 34 has been illustrated in Fig. 31. In this disclosure, instead of oscillating the truing tool, a rectilinear motion is imparted to the truing tool as will be hereinafter described. The truing tools 405 and 687 (Fig. 31) are mounted in a manner substantially the same as that shown in Fig. 30. An arm 694 supporting the truing tools is fixedly mounted relative to the longitudinal movable slide 373. A truing tool 693 is also mounted on the arm 694 for truing the face of the regulating wheel 191. A cam actuated mechanism is provided for moving the cross slide 363 which supports the work rest base 380 relative to the regulating wheel slide 176. A cam plate 695 is supported by a stud 696 carried by the slide 373. The cam 695 rides on a surface 697 of a block 698 carried by the base 175. The

cam plate is provided with a projection 699 which bears against a surface 700 fixedly mounted relative to the work rest base 380. The spring 450 which is identical with that described in connection with Figs. 21 and 23 is utilised for maintaining the cam 695 in operative engagement with the surface 697. The cam plate 695 is provided with an actuating lever 701. When it is desired to true the frusto-conical face 688 the lever 701 is rocked in a clockwise direction so that the release tension of the spring 450 serves to traverse the truing tool 687 across the frusto-conical face 688 to true the same. After the truing tool 687 has completed its pass across the face 688, the lever 701 is rocked in a counter-clockwise direction to again traverse the truing tool 687 in the reverse direction across the face 688.

Fig. 32 illustrates diagrammatically the arrangement of the grinding wheel 34, the regulating wheel 191, together with the work rest 382 and its supporting slide 373 for different set-ups for the truing and grinding operation. As illustrated in Fig. 32 truing tools 405 and 681 are utilized as shown in Fig. 28. The grinding wheel 34 is moved rearwardly to an inoperative or truing position after which the slide 373 is traversed longitudinally to true the operative face thereof. Similarly the regulating wheel is backed off and the slide 373 traversed longitudinally so that the truing tool 681 trues the face of the regulating wheel 191. The work rest 382 is positioned parallel to the axes of the grinding wheel 34 and the regulating wheel 191.

The diagrammatic illustrations in Figs. 33, 34, 35 and 36 have been shown arranged for grinding tapered work pieces but are also applicable to grinding other irregular surfaces of revolution. As shown in Fig. 33, the regulating wheel 191 and also the slide 373 are swivelled. With this arrangement, the grinding wheel 34 is trued by movement to an inoperative position and the slide 373 and the truing tool 405 are traversed longitudinally during which movement the truing tool 405 is moved transversely as governed by the forming bar arranged similar to forming bar 422 (Fig. 23). In this case the forming bar 422 is shaped and positioned to produce a taper on the periphery of the grinding wheel 34. The regulating wheel 191 in this case is trued by moving the regulating wheel to a truing position after which the slide 373 is traversed longitudinally so that the truing tool 693 trues the operative face thereof.

Fig. 34 shows a similar arrangement in which the truing tool 405 trues a cylindrical face on the periphery of the grinding wheel 34. The regulating wheel slide is swivelled to position the regulating wheel 191 as illustrated. In this case the regulating wheel is trued with a taper face as the truing tool 693 governed by a forming bar similar to forming bar 423 (Fig. 23) controls the transversing movement thereof to produce the desired taper. In this arrangement the work rest 382 and the slide 373 are arranged parallel to the axis of the grinding wheel.

The similar arrangement has been illustrated in Fig. 35 but with the work rest 382 positioned parallel to the axis of the regulating wheel 191. The slide 373 is arranged parallel to the axis of the grinding wheel 34. In this latter arrangement the regulating wheel 191 is swivelled and its operative face trued by traversing the truing tool 693 governed by a forming bar similar to forming bar 423 (Fig. 23) to true a taper face thereon. The grinding wheel 34 is trued by first positioning the grinding wheel 34 in a truing position after which a longitudinal traversing movement of the slide 373 traverses the truing tool 405 across the face of the grinding wheel 34 to true the same.

When it is desired to set the machine up for straight-through grinding, the pipe 606 is connected to the pipe 606*a* and the pipe 609 is connected to the pipe 609*a* to render the cylinder 714 operative. The cylinder 714 contains a slidably mounted piston 713 which is connected to the upper end of a piston rod 712. The lower end of the piston rod 712 is connected to a work stop plunger 711. Work pieces are placed on a work chute 710 where they slide axially under the influence of gravity on to the work rest 262 and pass through the grinding throat between the grinding wheel 34 and the regulating wheel 191. A compression spring 715 in the upper end of the cylinder 714 serves normally to hold the work stop plunger 711 in a downward position to hold the work piece from sliding into the grinding throat. When pressure is passed through the pipe 609 and 609*a* into the lower end of the cylinder 714 the work stop plunger 711 is moved upwardly against the compression of the spring 715 to allow work pieces to feed through the machine. As the ground work pieces pass toward the right (Fig. 37) after being ground they pass under a gauge 650*a*, the operation of which will be hereinafter described.

A different arrangement has been illustrated in Fig. 36 in which both of the wheels 34 and 191 are arranged with their axes parallel to each other. In this case the grinding wheel 34 is trued by first backing it off to a truing position after which the slide 373 is traversed longitudinally so that the truing tool 405 trues the operative face thereof. The regulating wheel 191 is trued by the truing tool 693 when it is traversed longitudinally during which movement a forming bar similar to the forming bar 423 (Fig. 23) imparts a transversing movement to the truing tool 693 to true the desired taper on the operative face thereof. In this latter arrangement the work rest 382 is positioned parallel to the axes of the grinding wheel 34 and the regulating wheel 191.

Referring now to Fig. 38, the switch SW1 is closed to convey electric power to the operating mechanism of the machine. The switch SW2 is closed to start the motor 35 to start rotation of the grinding wheel 34 and the regulating wheel 191 and to start the fluid pumps. A manually operable cycle control lever 705 is pivotally mounted on the front of the machine base (Figs. 1 and 38). When the lever 705 is rocked in a counter-clockwise direction, a start switch 706 is closed to energize a relay switch CR9 which sets up a holding circuit to maintain the relay switch CR9 energized. If it is desired to stop the cycle of the machine, the control lever 705 may at any time be shifted in a clockwise direction which serves to open a stop switch 707 thereby breaking the holding circuit to deenergize the relay switch CR9.

An electric timer T1 is provided which is operatively connected to control the duration of the infeeding movement of the grinding wheel during a plunge-cut grinding operation. An electric counter T2 is operatively connected to initiate a grinding wheel truing operation, at count-out, after a predetermined number of work pieces have been ground. An electric counter T3 is operatively connected with the work sizing gauge so that if a predetermined number of consecutive work pieces are ground over size, at the count-out, the counter serves to actuate the wheel feed compensator to impart a forward compensation of the wheel feeding mechanism so as to reduce the work size on succeeding work pieces to a predetermined size. An electric counter T4 is operatively connected with the work sizing gauge so that if a predetermined number of consecutive work pieces are ground under size, at the count-out, the counter actuates the wheel feed compensator to impart a rearward compensation to the wheel feed mechanism to increase the work size on succeeding work pieces to the predetermined size.

A switch SW3 is provided which in the position illustrated in Fig. 38 operatively connects the electric timer T1 to control the automatic operation of the infeeding mechanism automatically to grind successive work pieces. If it is desired to operate the machine for plunge-cut grinding manually, the switch SW3 is moved upwardly

(Fig. 38) which serves to render the timer T1 inoperative so that the plunge-cut grinding wheel may be manually controlled by the control lever 705 on successive grinding operations.

A selector switch SW5 is provided which in the position illustrated in Fig. 38 is set for a plunge-cut grinding operation. When it is desired to set up the machine for a straight-through feed operation, the switch SW5 is moved upwardly (Fig. 38). Switch SW6 is provided to render the switch SW5 operative or inoperative as desired. If the switch SW6 is opened, the work gauge mechanism will be rendered inoperative.

A selector switch SW4 is provided which in the position illustrated in Fig. 38 serves to render the automatic truing of the grinding wheel operative. If it is desired to manually control the truing of the grinding wheel, the switch SW4 is moved upwardly. In this latter position of the switch SW4, the electric counter T1 is rendered inoperative.

When switch SW1 is closed it conveys electric power to the machine and the following takes place:

(1) The clutch coil TCH2 of the counter T2 is energized through the switch SW4, and the normally closed (now closed) contacts of limit switch LS3, contacts LC2 of timer T2 closed and contacts RC2 open.

(2) Relay switch CR8 is energized through the normally open now held closed contacts of limit switch LS6.

(3) The clutch coil TCH3 of the counter T3 is energized through the normally closed contacts of the time relay switch TR3 and the contacts CC3 of counter T3 close to render the counter operative.

(4) The clutch coil TCH4 of the counter T4 is energized through the normally closed contacts of the time relay TR3 and the contacts CC4 of the counter T4 close to render the counter operative.

When the switch SW2 is closed, the motor 35 is started to drive the grinding wheel, the regulating wheel, and the hydraulic pumps. The starting of the hydraulic pumps serves when the grinding machine is set up for a straight-through feed grinding operation to raise the work stop plunger 711 (Fig. 37) so that work pieces to be ground start passing along the work rest 262, through the grinding throat between the grinding wheel 34 and the regulating wheel 191 to grind the work pieces to a predetermined isze. As the ground work pieces leave the grinding throat they pass under the work gauge 650*a* (Fig. 37) which is intermittently moved into a gauging position at intervals controlled by the time delay relay TR2 when TR2 is set for adjustable time delay.

When the grinding machine is set-up for plunge-cut grinding, the cycle control lever 705 is moved in a counterclockwise direction, a starting switch 706 is closed to energize a relay switch CR9 which sets up a holding circuit to maintain relay CR9 energized. The relay CR9 remains energized during operation of the machine until a stop switch 707 is actuated by a clockwise movement of the control lever 705 when it is desired to stop the grinding cycle. The closing of starting switch 706 serves through the now closed contacts of the limit switch LS4, the contacts LC2 of the counter T2, and normally open now closed contacts of LS7, through now closed contacts of relay CR8 to energize relay switch CR1 and the solenoid S1. The energizing of solenoid S1 serves to actuate the feed control valve 530 to start a plunge-cut feeding movement of the grinding wheel 34. Also through the same circuit, clutch coil TCH1 of the timer T1 is energized. When TCH1 is energized, contacts LC1, RC1 and CC1 are closed. If switch SW3 is in an automatic position (as above shown in Fig. 38) a holding circuit is set up through the contacts RC1 to maintain timer T1 operative, to maintain CR1 and solenoid S1 energized until the timer T1 times-out as will be hereinafter described. Similarly when SW3 is in a manual position, a holding circuit is set up through the contacts LC1 to maintain the timer T1 operative and to maintain relay switch CR1 and solenoid S1 energized until the timer T1 times-out as will be hereinafter described. When the solenoid S1 is energized to start an infeeding movement of the piston 75 toward the right, the feed wheel 67 starts rotating in a counter-clockwise direction to rock the feed pawl 22 in a counter-clockwise direction to allow the normally closed contacts of LS7 to close to start the timing motor of timer T1 which thereafter serves to control the duration of the grinding cycle.

When the contacts CC1 of timer T1 close the time relays TR2 and TR3 are energized. The contacts of TR2 close (immediately close and open for plunge-cut grinding and are adjustably timed for through-feed grinding) to energize the solenoid S2. Energizing solenoid S2 serves to shift the control valve 632 so that fluid under pressure is passed through the pipe 643 into the cylinder chamber 642 to move the piston 626 together with the work ejector rod 625 toward the right (Fig. 37) and to move the gauge piston 654 upwardly to cause a downward movement of the work sizing gauge 650 to an operative position. When gauge 650 moves down into a gauging position, the normally closed contacts of limit switch LS2 close to complete a circuit to energize the count coil ACH2 of counter T2 to impart a count impulse thereto. After a predetermined number of such impulses, the counter T2 serves to initiate a grinding wheel truing operation.

When the gauging head 650 moves downwardly to a gauging position the V-surface 651 engages the peripheral surface of the ground work piece. The gauge-plunger 652 is moved upwardly relative to the V-surface 651 so as to actuate the limit switch LS1. If the ground work piece is within predetermined size limits, the normally closed contacts of the limit switch LS1 open and the normally open contacts thereof remain open. If the ground work piece is under size, the gauge-plunger 652 moves upwardly a greater distance relative to the V-surface 651 and closes the normally open contacts of the limit switch LS1, which serves at count-out of the counter T3 to energize the solenoid S3*a* to shift the valve member 576 toward the left (Fig. 37). The valve 575 in this position passes fluid under pressure through the pressure pipe 153, through the valve chamber 578, through the pipe 147 to cause an upward movement of the piston 143 which causes a rearward compensation to the feeding mechanism, that is, it positions the grinding wheel 34 so that on the next infeeding movement the grinding wheel 34 will not advance quite as far toward the work axis and grind the work to the predetermined size.

Similarly if the ground work piece is over size, the gauge-plunger 652 does not move upwardly relative to the V-surface 651 thereby allowing the normally closed contacts of the limit switch LS1 to remain closed which serves at count-out of the counter T4, after a predetermined number of successive work pieces have been ground oversize, to energize the solenoid S3*b* which shifts the valve member 576 toward the right (Fig. 37) so that fluid under pressure from the pipe 153 passes through the valve chamber 578, through the pipe 111 to cause an upward movement of the piston 97. The upward movement of the piston 97 imparts a forward compensation to the wheel feeding mechanism, that is, advances the position of the grinding wheel 34, so that on the next grinding operation the grinding wheel will advance a further distance toward the axis of the work piece being ground to grind it and successive work pieces to a predetermined size. It will be readily apparent from the foregoing disclosure that the gauging head 650 is moved to and from an operative position on successive ground work pieces and after a predetermined number of such movements when a predetermined number of successive work pieces are either under size or over size, automatically imparts a compensating adjustment to the wheel feed mechanism so that the work pieces will thereafter be ground to the desired predetermined size.

When the feed piston 75 starts moving toward the right to cause an infeeding movement of the grinding wheel 34, the feed pawl 22 is rocked in a counter-clockwise direction so that the normally closed contacts of limit switch LS7 close and the normally open contacts thereof open. The closing of the normally closed contacts of LS7 serves to start the motor M of timer T1 to start the timing cycle and at the same time energize solenoid S6 to shift the valve member 611 toward the right. When valve member 611 is in a right hand end position fluid under pressure from the pipe 153 passes through the valve chamber 613, through the pipe 606 into the lower end of the cylinder 605 to cause an upward movement of the piston 604 to release a new work piece from the work hopper 590 onto the work rest 382 for the next grinding operation. The grinding wheel 34 continues its infeeding movement until the stop abutment 20 on the feed wheel 67 engages the stop surface 21 on the feed pawl 22 which serves as a positive stop to limit the infeeding movement of the grinding wheel. The grinding wheel 34 remains in operative grinding engagement with the work piece until the timer T1 times-out.

During the plunge-cut grinding operation the ejector rod 625 is in a right hand end position with the piston 626 in engagement with the stop screw 631. In this position, the left hand end of the ejector rod 625 serves as a stop to position the work piece during a plunge-cut grinding operation.

When the timer T1 times-out after a predetermined time interval, the contacts LC1, RC1 and CC1 open to deenergize the time delay relays TR2 and TR3, to de-energize TCH1 of the timer T1 so as to allow timer T1 to reset and also to de-energize the solenoid S6, relay switch CR1, solenoids S1 and S2. When S6 is de-energized, the piston 604 moves downwardly into a lower position, as shown in Fig. 37, so as to allow the next work piece to drop into a lower or loading position at the bottom of the hopper 590. De-energizing the solenoid S2 releases the compression of the spring 638 to shift the valve member 633 toward the left so that fluid under pressure is passed to the upper end of the cylinder 653 to cause a downward movement of the piston 654 thereby moving the gauge 650 upwardly to an inoperative position. At the same time fluid under pressure is passed from the valve 632 through the pipe 639 into the right hand end of the cylinder 627 to move the ejector rod 625 toward the left thereby ejecting the grinding work piece in an axial direction toward the left (Fig. 37) into a gauging position. This movement of the ground work piece serves to move the previously ground work piece from a gauging position into the discharge chute 624.

When solenoid S1 is de-energized the feed piston 75 moves toward the left into the position illustrated in Fig. 37 so as to cause a rearward movement of the grinding wheel to an inoperative position. During this movement of the piston 75, the feed wheel 67 moves in a clockwise direction so that the released tension of the spring 24 actuates the limit switch LS7 to open the normally closed contacts thereof and to close the normally open contacts thereof to energize TCH1 of the timer T1 to make ready the timer T1 and to start the next grinding cycle. When TCH1 is enregized contacts LC1, RC1 and CC1 close as previously described to start the next grinding cycle.

When the normally closed contacts of limits switch LS2 close and open a predetermined number of times, a predetermined number of impulses are sent to the count coil ACH2 of the counter T2 after which the counter T2 counts-out. At count-out of counter T2, contacts LC2 open to prevent the wheel slide 11 from moving forward again by deenergizing relay switch CR1 and the solenoid S1. The normally closed contacts of RC1 are now closed. The contacts RC2 of counter T2 close to energize the time delay relay TR4. (TR4 is a time delay relay which is set for a time delay upon energization. Contacts of TR4 close after a time interval. This is used when the machine is set up for through feed grinding to allow the last ground work piece to pass from the machine before a truing operation is performed. When RC2 closes and SW5 is set for through feed grinding, solenoid S6 is energized to actuate the work stop plunger 711 to stop the flow of work pieces from the machine.)

When the time relay TR4 times-out, the contacts thereof close and through switch SW4, now closed contacts of CR8, through now closed contacts of LS5 to energize CR7. Normally open contacts of CR7 close to energize CR4 and S4. Energizing solenoid S4 shifts the valve 168 toward the right to pass fluid under pressure through pipe 159 to move the piston 156 together with the wheel slide 11 toward the left (Fig. 37) into a truing position with the piston 156 in engagement with the truing stop 160. Movement of the wheel slide 11 into this position opens the normally closed contacts of LS3 and closes the normally open contacts of LS3, also allows the normally open contacts of LS6 to open so as to de-energize the relay switch CR8. Opening the normally closed contacts of LS3 serves to de-energize TCH2 and thereby resets the counter T2. Closing the normally open contacts of LS3 serves to energize solenoid S5 to traverse the slide 253 and the truing tool 307 toward the right (Fig. 37) across the operative face of the grinding wheel 34. Also valve 325 in this position passes fluid under pressure through the pipe 125 to move piston 116 toward the right to actuate the wheel truing compensating mechanism so as to advance the grinding wheel before the truing tool 307 passes across the face thereof, by a predetermined amount. As slide 253 moves toward the right, the normally open contacts of limit switch LS4 open and the normally closed contacts of LS4 close to hold relay switch CR4 and solenoid S4 energized until the slide 253 returns to its initial position as shown in Fig. 37. When the slide 253 reaches a right hand end position, the normally closed contacts of relay switch LS5, now serving to maintain a holding circuit closed, open to break the holding of the circuit to de-energize the relay switch CR7 and the solenoid S5 so as to return the slide 253 toward the left to its initial position and also to return the compensating piston 116 toward the left into its initial position.

When the truing slide 253 reaches a left hand or starting position, the normally open contacts of limit switch LS4 close and the normally closed contacts of LS4 open. Opening normally closed contacts of LS4 served to de-energize the relay switch CR4 and the solenoid S4. De-energizing the solenoid S4 shifts the valve 168 toward the left so that fluid under pressure is passed through the pipe 158 to move the piston 156 together with the wheel slide 11 toward the right from a truing position into a grinding position, as shown in Fig. 37.

When the wheel slide starts moving forward to a grinding position, the normally open contacts of the limit switch LS3 open and the normally closed contacts of the limit switch LS3 close so that when the wheel slide reaches a forward or grinding position, the normally open contacts of the limit switch LS6 close to energize relay switch CR8 and the normally open contacts of CR8 close. Closing the normally closed contacts of the limit switch LS3 serves to energize TCH2 of counter T2 thereby opening contacts RC2 and closing contacts LS2. Opening contacts RC2 serves to de-energize the time relay TR4 (and solenoid S6 if the machine is set for through feed grinding to raise the work stop plunger 711 so that work pieces may start passing through the machine). Closing contacts LC2, of counter T2, completes a circuit to start a grinding cycle as above described.

When it is desired to set up the grinding machine for a straight-through grinding operation, cylinder 605 is disconnected and pipes 606 and 609 are connected to

pipes 606*a* and 609*a*, respectively, thereby rendering the cylinder 714 operative. The work ejector rod 625 and cylinder 627 are removed from the machine, and the valves 640 and 644 are closed during the straight-through grinding operation of the machine. The plunge-cut work hopper 591 together with associated parts are also removed from the machine. The gauge 650 and the actuating mechanism therefor are set-up with the gauge 650 in position 650*a* (Fig. 37) so as to gauge ground work pices as they pass axially from the grinding throat. In a straight-through grinding operation, the grinding wheel 34 and the wheel slide 11 remain in a forward position, that is toward the right (Fig. 37) in which position the normally open contacts of the limit switch LS6 are held closed to maintain relay switch CR8 energized. The selector switch SW3 is shifted upwardly (Fig. 38) into a manual position and the cycle control lever 705 is rocked in a clockwise direction to actuate the stop switch 707 thereby breaking the holding circuit to de-energize relay switch CR9. This renders the timer T1 inoperative.

The selector switch SW5 is moved upwardly (Fig. 38) into a through-feed position so as to energize time relays TR2 and TR3 through the now held closed normally open contacts of LS2. The time relay TR2 is adjusted for a time delay on energization. The contacts of time relay TR2 close immediately but are timed to open after a predetermined time interval. The closing of contacts of time relay TR2 energizes the solenoid S2 to shift the valve 632 toward the right (Fig. 37) so that fluid under pressure is passed to the lower end of the cylinder 653 to cause an upward movement of the piston 654 thereby moving the gauge 650*a* downwardly to an operative position. During the downward movement of the gauge 650*a*, the normally open contacts of limit switch LS2 open but time relay TR2 and TR3 are held operative by a holding circuit through a pair of contacts of the time relay TR2 and the normally closed contacts of relay CR4. As the gauge 650*a* moves downwardly the normally closed contacts of the limit switch LS2 close and when opened again operate the count coil ACH2 of the counter T2.

When the gauge 650*a* is in a downward position, the limit switch LS1 operates to actuate either the count coil of the counter T3 or T4, provided the work pices are either over size or under size, the same as described in connection with the plunge-cut grinding operation.

When time relay contacts of time relay TR2 open, the holding circuit is broken and TR3 and TR2 are de-energized to de-energize the solenoid S2 thereby releasing the compression of the spring 638 to shift the valve member 633 into a left hand end position as illustrated in Fig. 37. In this position of the valve 632 fluid under pressure is passed to the upper end of the cylinder 653 to cause a downward movement of the piston 654 so as to raise the gauge 650*a* to an inoperative position. Movement of the gauge to an inoperative position opens the normally closed contacts of the limit switch LS2 thereby completing a counting impulse to the count coil ACH2 of the counter T2. The normally open contacts of the limit switch LS2 are closed to again energize time relays TR2 and TR3 to move the work gauge 650*a* to an operative position at intermittent intervals as controlled by the setting of the time relay TR2.

At count-out of counter T2, the grinding wheel 34 is automatically trued in a manner identical to that described in connection with the plunge-cut operation. As the counter T2 counts-out, the contacts RC2 close to energize the solenoid S6 to cause a downward movement of the work stop plunger 711 so as to prevent the work pieces passing through the machine during a truing operation. When the contacts RC2 close, the time relay TR4 is also energized and after a short time delay the contacts close to initiate a truing operation the same as described in connection with the plunge-cut grinding operation.

When the machine is set up for straight-through grinding, as soon as fluid pressure is started, the work stop plunger 711 is raised to an inoperative position. Work pieces to be ground are then either automatically or manually placed in the work chute 710 and are fed axially through the grinding throat between the grinding wheel 34 and the regulating wheel 191. As previously described, the regulating wheel 191 is skewed so that its axis is at an angle to the axis of the grinding wheel and the work rest so as to impart the desired axial feeding component to the work pieces as they pass through the machine. The rate of axial feed may be adjusted by varying the skew angle of the regulating wheel 191 relative to the grinding wheel 34.

When it is desired to true the regulating wheel 191 in setting up the grinding machine, the grinding wheel 34 and the wheel slide 11 are backed-off in a rearward direction by manual rotation of the feed wheel 67 through a sufficient distance so that when the grinding wheel slide 11 is moved to a truing position there will be ample clearance between the grinding wheel truing tool 405 and the operative face of the grinding wheel when the slide 253 is traversed for a regulating wheel truing operation. To true the regulating wheel 191, the switch SW4 is shifted upwardly (Fig. 38) into a manual position to render the counter T2 inoperative. The truing tool 410 is mounted on the bracket 400. The manually operable switch SW7 is then momentarily closed to energize relay switch CR7 through the closed contacts of relay switch CR8 and the normally closed contacts of relay switch LS5. The closing of contacts of relay switch CR7 energize the relay switch CR4. The closing of the contacts of relay switch CR4 energizes the solenoid S4 and also through another pair of contacts of the relay switch CR4 and through the manually operable switch SW4, CR8 and LS5 sets up a holding circuit to maintain relay switch CR7, relay switch CR4 and solenoid S4 energized. Energizing the solenoid S4 serves to move the grinding wheel 34 and the wheel slide 11 rearwardly to a truing position where it remains during a regulating wheel truing operation. When the wheel slide 11 moves rearwardly to a truing position, the normally open contacts of the limit switch LS3 close energizing the solenoid S5 to start a traversing movement of the truing tool slide 253 toward the right as previously described. The truing tool slide 253 makes one complete reciprocation and stops. The regulating wheel may be fed toward the truing tool 410 by manual actuation of the feed wheel 191 to facilitate truing the desired amount from the periphery surface of the regulating wheel. If more than one complete reciprocation of the truing tool is required to true the regulating wheel 191 to the desired extent, the manually operable switch SW7 may be actuated to initiate each complete reciprocation thereof.

It will thus be seen that there has been provided by this invention a centerless grinding machine in which the various objects hereinabove set forth together with many thoroughly practical advantages are successfully achieved. As many possible embodiments may be made of the above invention and as many changes might be made in the embodiment above set forth, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. In a centerless grinding machine, a rapidly rotating grinding wheel, a regulating wheel opposed thereto, driving means for rotating the regulating wheel at a slow speed for a grinding operation or at a faster speed for a wheel truing operation, a feeding mechanism including a nut and screw mechanism for causing a transverse feeding movement between said wheels, means to impart a rotary motion to said feed screw to produce a plunge-cut grinding feed, a work gauge arranged to intermit-

tently move into gauging contact with a ground work piece, a feed compensating mechanism operatively connected to impart a rotary motion to said feed nut in one direction to compensate for over size work, a second compensating mechanism operatively connected to impart a rotary motion to said feed nut in the opposite direction to compensate for under size work, means to intermittently move the gauging device into operative engagement with successive ground work pieces, an electric counter operatively connected to receive an impulse after each movement of said gauge to and from operation position, and a limit switch actuated by said gauge which is arranged so that after a predetermined number of work pieces have been ground at count-out of the counter to actuate either one or the other of said compensating mechanisms to facilitate grinding succeeding work pieces to the desired predetermined size.

2. In a centerless grinding machine, as claimed in claim 1, in combination with the parts and features therein specified of a grinding wheel truing apparatus including a longitudinally reciprocable slide, a truing tool mounted thereon, a piston and cylinder to actuate said slide, a solenoid-actuated control valve therefor, a limit switch actuated by and in timed relation with the infeed mechanism, an electric counter actuated thereby, said counter serving at count-out to actuate said solenoid valve to initiate a reciprocating movement of the truing tool across the operative face of the grinding wheel.

3. In a centerless grinding machine, as claimed in claim 2, in combination with the parts and features therein specified of a fluid pressure actuated compensating mechanism operatively connected to impart a rotary motion to said feed nut to advance the grinding wheel by a predetermined increment before the truing tool passes across the operative face of the grinding wheel.

4. In a centerless grinding machine, as claimed in claim 3, in combination with the parts and features therein specified, in which the truing compensating mechanism comprises a piston and cylinder actuated rack bar for imparting a rotary motion to said feed nut to advance the grinding wheel by an amount equal to the amount to be trued from the grinding wheel, and operative connections between said piston and cylinder and the solenoid-actuated valve so that the compensation is made at the same time the traversing movement of the truing tool is started.

5. In a centerless grinding machine, the combination of a base, a work support thereon, a grinding wheel support on said base, means to feed one of said supports to and from the other including a nut and screw feed mechanism, a work sizing gauge intermittently to engage successive finished ground work pieces, a feed compensating mechanism controlled by the sizing gauge including a forward compensating mechanism to impart a rotary motion to said feed nut in one direction to advance the grinding wheel support so as to compensate for over size work, and a rearward compensating mechanism to impart a rotary motion to said feed nut in the opposite direction to cause a rearward motion to the wheel support so as to compensate for under size work.

6. In a centerless grinding machine, as claimed in claim 5, in combination with the parts and features therein specified of means intermittently to move said sizing gauge into operative engagement with successive ground work pieces, an electric counter actuated by movement of said gauge to and from an operative position, and means including a limit switch on said gauge which serves at count-out of said counter to actuate one of said compensating mechanisms when a predetermined number of successive work pieces have been ground either over size or under size.

7. In a centerless grinding machine, a rapidly rotating grinding wheel, a slowly rotating regulating wheel opposed thereto, a work rest to support a work piece between said wheels, a feeding mechanism including a nut and screw mechanism for causing a transverse feeding movement between said wheels, means to impart a rotary motion to said feed screw to produce a plunge-cut grinding feed, a work gauge arranged to intermittently move into gauging contact with a ground work piece, a feed compensating mechanism operatively to impart a rotary motion to said feed nut in one direction to compensate for over size work, a second compensating mechanism operatively connected to impart a rotary motion to said feed nut in the opposite direction to compensate for under size work, means to intermittently move the gauging device into operative engagement with successive work pieces, an electrical means operatively connected to receive an impulse during each movement of said gauge to and from operative position, and a means including a limit switch actuated by said gauge which is arranged so that after a predetermined number of successive work pieces have been ground to actuate either one or the other of said compensating mechanism to facilitate grinding successive work pieces to a predetermined size.

8. In a centerless grinding machine, as claimed in claim 7, in combination with the parts and features therein specified, of means including a worm and worm gear mechanism to impart a rotary motion to said feed nut in one direction, a second worm and worm gear mechanism operatively connected to impart a rotary motion to said feed nut in the opposite direction and means including independent hydraulically actuated pawl and ratchet mechanism independently to actuate one or the other of said worm and worm gear mechanisms so as to compensate for over size or under size work pieces after a predetermined number of work pieces have been ground either over size or under size.

9. In a centerless grinding machine, as claimed in claim 8, in combination with the parts and features therein specified of independent manually operable means to adjust each of said compensating mechanisms.

10. In a centerless grinding machine having a transversely movable rotatable grinding wheel, a transversely movable rotatable regulating wheel, means including a nut and screw feed mechanism to cause a relative transverse feeding movement between said wheels, a manually operable feed wheel to rotate said feed screw, means including a piston and cylinder operatively connected to impart a rotary motion to said feed screw at a grinding rate, a positive stop to limit the infeeding movement of said screw, an electrical timer operatively connected to control the duration of the grinding cycle, a work gauge, means intermittently to move said gauge into engagement with successive ground work pieces, a feed compensating mechanism operatively connected to impart a rotary motion to said feed nut in one direction to compensate for over size work, a second feed compensator operatively connected to impart a rotary motion to said feed nut in the opposite direction to compensate for under size work, and operative connections between said gauge and said compensators to actuate the compensators only after a predetermined number of successive work pieces are ground either over size or under size.

11. In a centerless grinding machine, a rapidly rotating grinding wheel, an opposed slowly rotating regulating wheel, a work rest therebetween for supporting a work piece to be ground relative to said wheels, means including a fluid pressure actuated mechanism to impart a relative transverse feeding mechanism to said wheels to grind successive work pieces to a predetermined size, means including a fluid pump to supply fluid under pressure to said feeding mechanism, a single driving motor and means including driving connections operatively connected between said motor, said grinding wheel, said

regulating wheel and said pump to rotate the grinding wheel at grinding speed, the regulating wheel at a slow work regulating speed, and also to drive said fluid pump.

12. In a centerless grinding machine, as claimed in claim 11, in combination with the parts and features therein specified of a speed control driving mechanism for rotating the regulating wheel at a relatively slow speed to control rotation of the work being ground during a grinding operation, or at a relatively high speed suitable for a wheel truing operation.

13. In a centerless grinding machine, as claimed in claim 10, in combination with the parts and features therein specified of a grinding wheel truing apparatus including a longitudinally traversable truing tool, means including a piston and cylinder to traverse said tool across the operative face of the grinding wheel at a relatively fast speed in one direction and at a relatively slow speed in the opposite direction, means including a piston and cylinder operatively connected to move the feed screw rearwardly into a truing position after a predetermined number of work pieces have been ground, a solenoid-actuated control valve for said truing cylinder, means including a limit switch actuated by movement of the feed screw to a truing position to initiate a traversing movement of the truing tool.

14. In a centerless grinding machine, as claimed in claim 13, in combination with the parts and features therein specified of a feed compensating mechanism including a piston and cylinder actuated rack and gear mechanism operatively connected to impart a rotary motion to the feed nut to advance the grinding wheel by a predetermined amount for a truing operation, and operative connections between the control valve and the piston and cylinder actuated rack and gear mechanism which serve to cause a compensating feed of the wheel toward the truing tool simultaneously with the starting of the truing tool traverse.

15. In a centerless grinding machine, having a rapidly rotating grinding wheel and a slowly rotating regulating wheel, a work rest located between said wheels, a longitudinally movable slide to support said work rest, a truing tool supported on said slide, means to move said grinding wheel away from said regulating wheel into a predetermined truing position, means including a piston and cylinder to traverse said truing tool and its supporting slide between said wheels in a direction parallel to the axis of rotation of the grinding wheel to traverse the truing tool across the operative face of the grinding wheel to true the same.

16. In a centerless grinding machine, as claimed in claim 15, in combination with the parts and features therein specified, of means including a forming bar and a follower arranged to impart a transverse movement to the truing tool during this transversing movement so as to true a predetermined shape on the operative face of the grinding wheel.

17. In a centerless grinding machine, as claimed in claim 15, in combination with the parts and features therein specified, of a pivotal support for the longitudinally traversing slide to facilitate swivelling the slide in a horizontal plane so that the path of movement of the truing tool is at an angle to the axis of the grinding wheel to true a predetermined taper thereon.

18. In a centerless grinding machine, as claimed in claim 17, in combination with the parts and features therein specified of a pivotal support for the work rest on said slide to facilitate swivelling the work rest in a horizontal plane so that the work rest is either parallel to or at an angle to the axis of the grinding wheel.

19. In a centerless grinding machine, as claimed in claim 15, in combination with the parts and features therein specified, of a second truing tool mounted on said longitudinally movable slide opposed to the first truing tool and arranged for truing the operative face of the regulating wheel, and means including an independent forming bar and a follower which are operativley connected and arranged to impart a transverse movement to said truing tool during a longitudinal traversing movement thereof to true a perdetermined shape on the periphery of the regulating wheel.

20. In a centerless grinding machine, a transversely movable wheel slide, a rotatable grinding wheel thereon, a transversely movable regulating wheel slide, a rotatable regulating wheel thereon, means to rotate said wheels respectively at a grinding and regulating rate of speed, means to impart a relative traverse feeding movement between said slides, means to swivel one of said slides about a vertical axis in a horizontal plane to facilitate angularly positioning the axes of the regulating wheel and the grinding wheel, a work rest located between said wheels for supporting a work piece to be ground, and means to swivel said work rest in a horizontal plane so that it may be positioned parallel to or at an angle to one of said wheel axes.

21. In a centerless grinding machine, as claimed in claim 20, in combination with the parts and features therein specified, of a longitudinally movable slide to support said work rest, a grinding wheel truing apparatus including a truing tool on said slide which is arranged to true the periphery of the grinding wheel, as it is traversed between said wheels, the second truing tool supported by said slide and arranged to true a frusto-conical side face on one side of the grinding wheel and manually operable means to impart a transverse movement to said second truing tool to traverse it across the side face of the wheel to facilitate truing a frusto-conical side face on the grinding wheel for a shoulder grinding operation.

22. In a centerless grinding machine, as claimed in claim 21, having a pivotally mounted support for the truing tool, a stop normally to position said support to position the first truing tool for truing the peripheral face of the grinding wheel, and means including a manually operated cam-actuated mechanism to impart a rocking motion to said support to traverse the second truing tool across a portion of the side face of the grinding wheel to true a frusto-conical face thereon.

23. In a centerless grinding machine, as claimed in claim 20, in combination with the parts and features therein specified of a transversely movable slide to support said longitudinally movable slide, a truing tool on said longitudinally movable slide to true the grinding wheel as the longitudinally movable slide is moved longitudinally to pass the truing tool between the operative face of the grinding and regulating wheels, a second truing tool on said slide arranged to true a frusto-conical side face on one side of the grinding wheel, and means including a manually operable cam-actuated mechanism to impart a transverse movement to said transversely movable slide to facilitate traversing the second truing tool across a portion of the side face of the wheel to facilitate truing the grinding wheel for a shoulder grinding operation.

24. In a centerless grinding machine having transversely rotatable grinding wheel, a transversely movable rotatable regulating wheel, means including a nut and screw feed mechanism to cause a relative transverse feeding movement between said wheels, a manually operable feed wheel to rotate said screw, means including a piston and cylinder operatively connected to impart a rotary motion to said feed screw at a grinding rate, a feed control valve to control the admission to and exhaust of fluid from the feed cylinder, and a shuttle-type gap eliminator valve operatively connected between said control valve and said cylinder to facilitate an initial rapid exhaust of fluid from the feed cylinder to rapidly close-up of the gap between the grinding and regulating wheels at the start of a grinding cycle.

25. In a centerless grinding machine, as claimed in claim 24, in combination with the parts and features therein specified of a piston and cylinder operatively con-

nected to cause an axial movement of the feed screw to facilitate rapidly moving the grinding wheel to a truing position, an adjustable stop to determine the truing position of said piston, and means precisely to adjust said stop to facilitate compensation for truing tool wear.

26. In a centerless grinding machine, as claimed in claim 24, in combination with the parts and features therein specified of a feed compensating mechanism to rotate said feed nut in one direction to impart a forward compensating movement to a grinding wheel, a feed compensating mechanism connected to impart a rotary motion to the feed nut in the opposite direction to impart a rearward compensating adjustment to the grinding wheel, and means to clamp the feed screw against a rotary motion during actuation of the compensating mechanisms.

27. In a centerless grinding machine having a base, a rotatable grinding wheel and a rotatable regulating wheel thereon, a work rest located between said wheels, a transversely adjustable slide on said base, longitudinally movable slide on said transversely adjustable slide to support said work rest, means including a pivotally mounted truing tool on said longitudinally movable slide, an adjustable stop normally to position said truing tool, means including a piston and cylinder to move said slide longitudinally so as to pass the truing tool across the operative base of the grinding wheel, and means including an adjustably mounted forming bar on said truing tool and a follower adjustably mounted on said transversely adjustable slide to facilitate truing a slight taper on the entry edge of said grinding wheel.

References Cited in the file of this patent

UNITED STATES PATENTS

2,033,335	Haas et al.	Mar. 10, 1936
2,438,239	Toulmin	Mar. 23, 1948
2,718,101	Stuckey et al.	Sept. 20, 1955
2,745,221	Comstock	May 17, 1956

FOREIGN PATENTS

603,673	Great Britain	June 21, 1948
722,671	Germany	June 16, 1942