

Dec. 13, 1955

W. K. LOWE  
BILLET GRINDER

2,726,490

Filed April 1, 1952

10 Sheets-Sheet 1

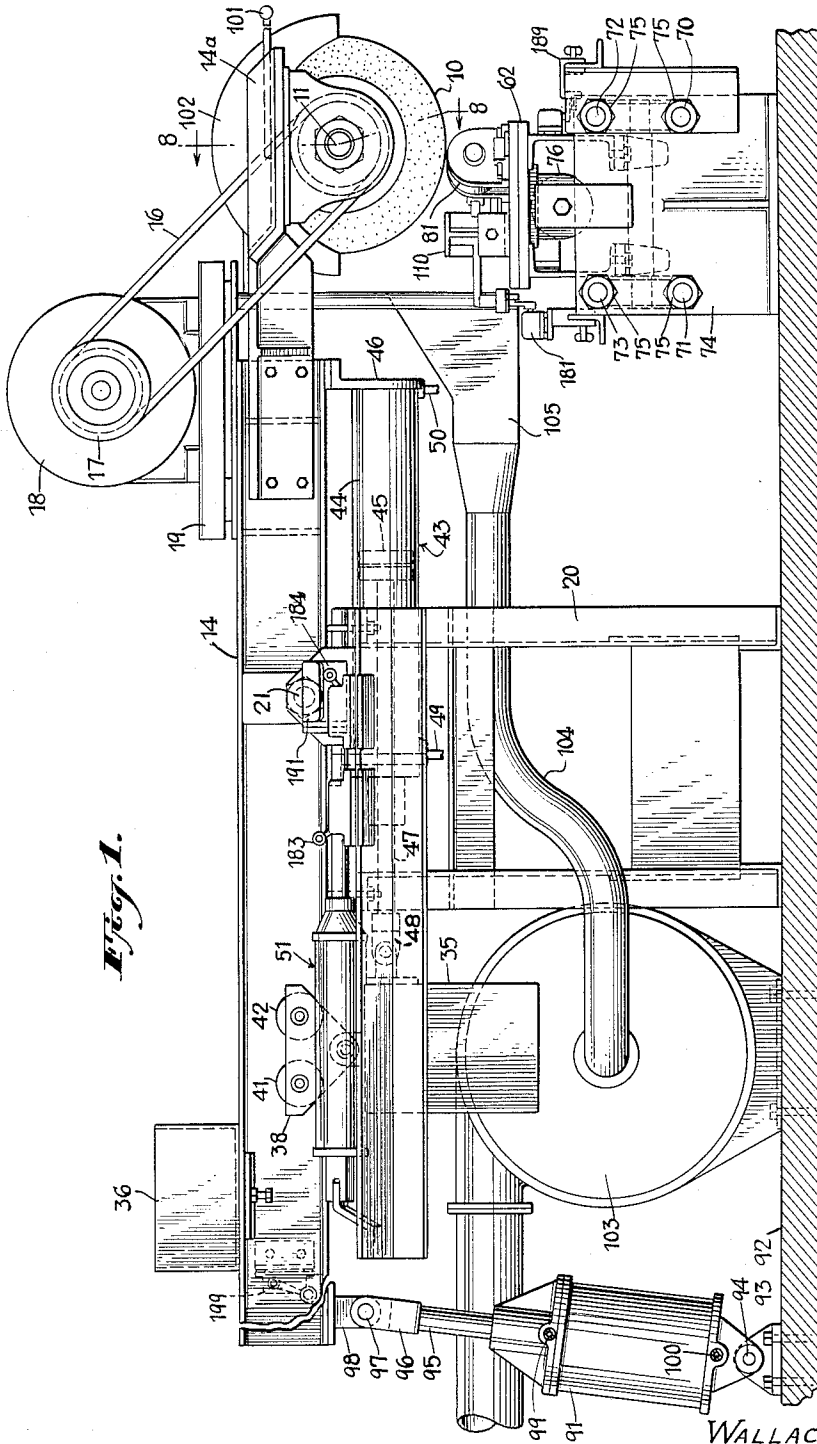


**Fig. 1.**

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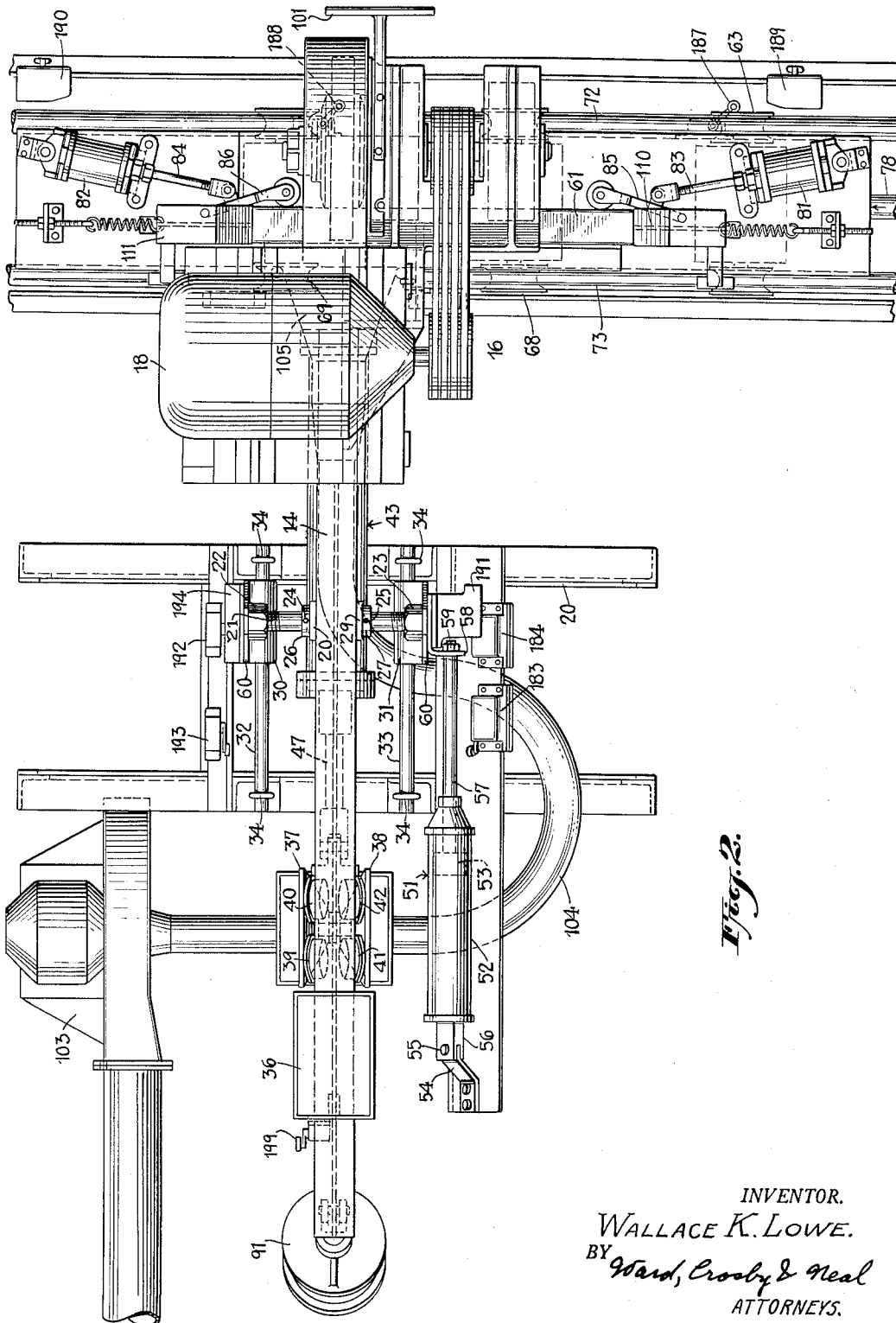


Fig. 2.

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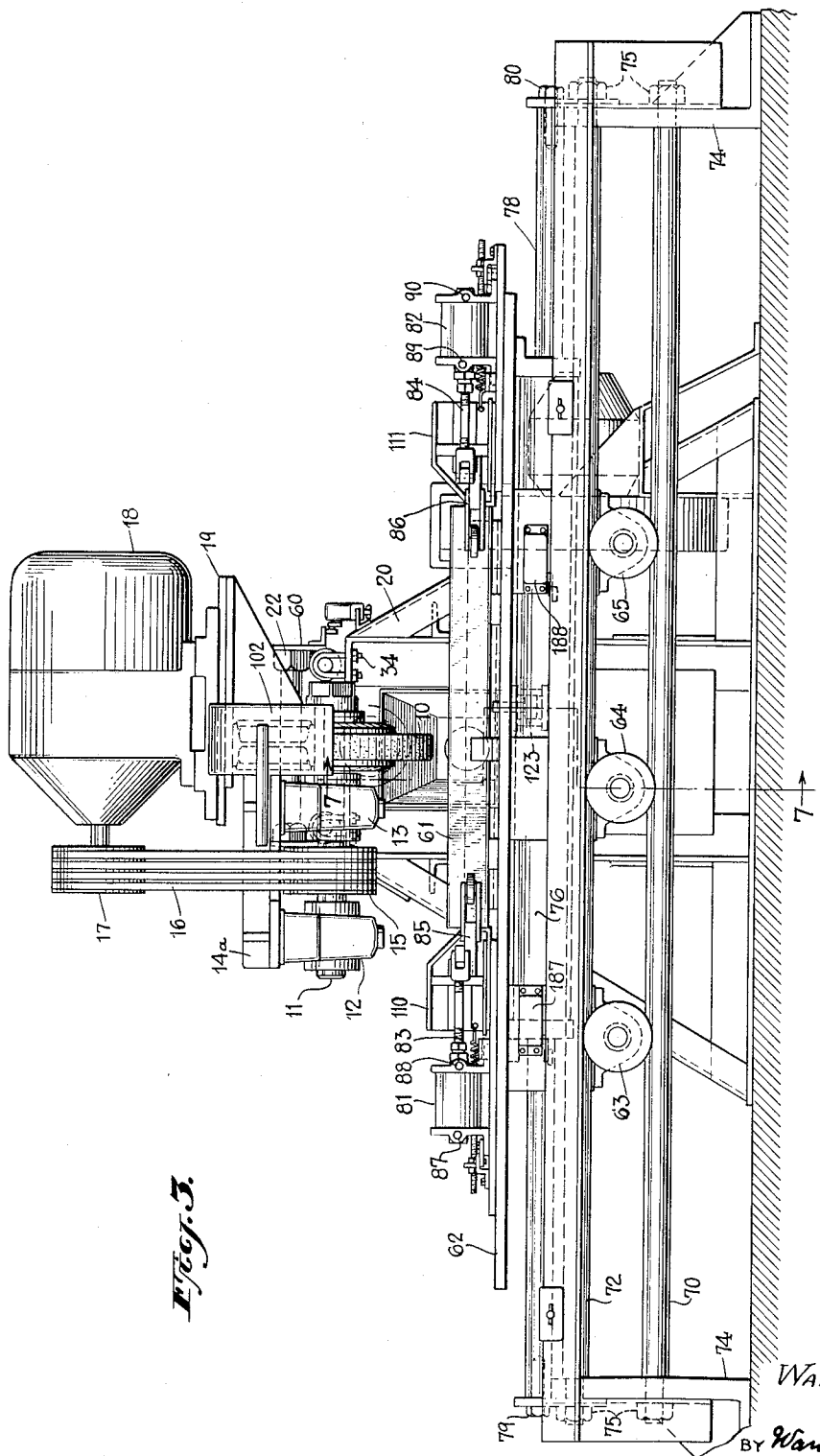


Fig. 3.

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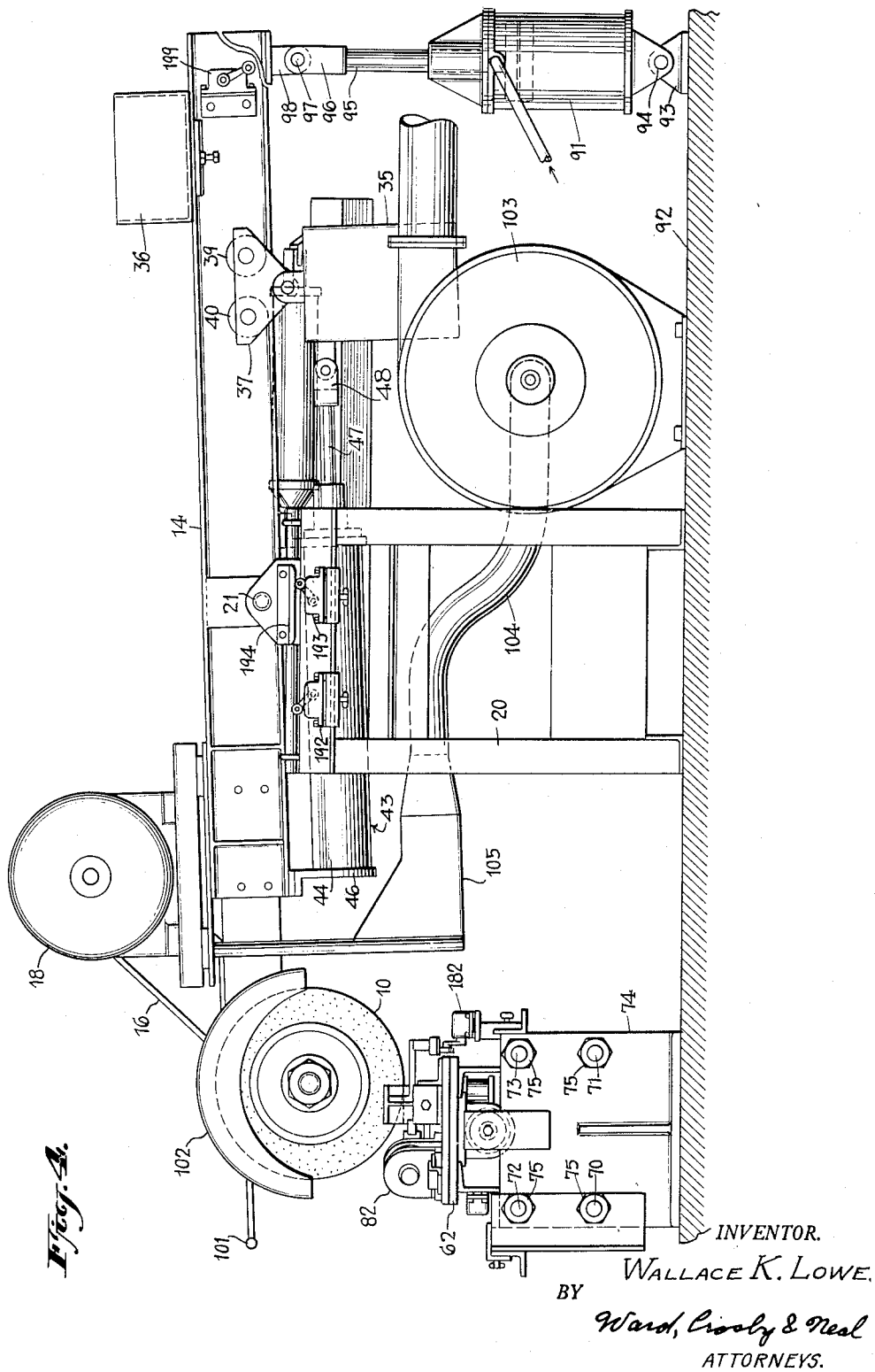
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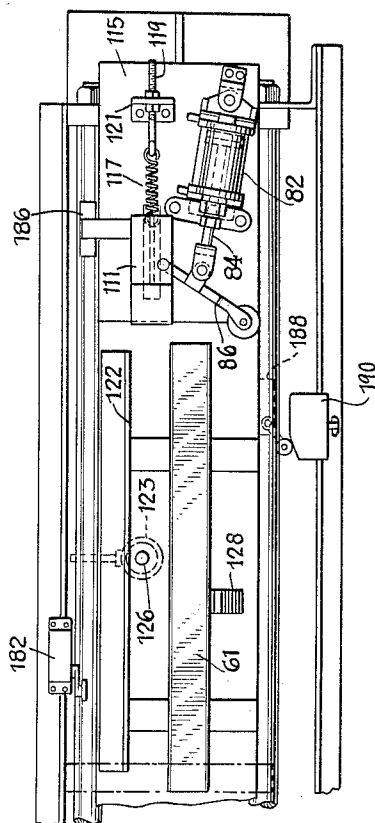
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BILLET GRINDER

Filed April 1, 1952

10 Sheets-Sheet 5



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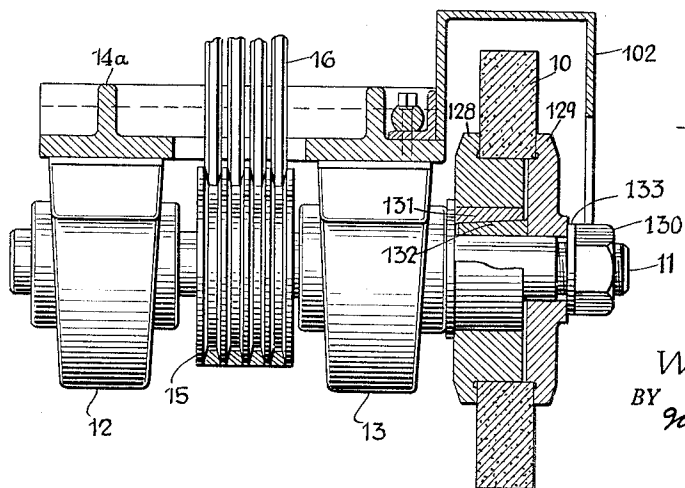
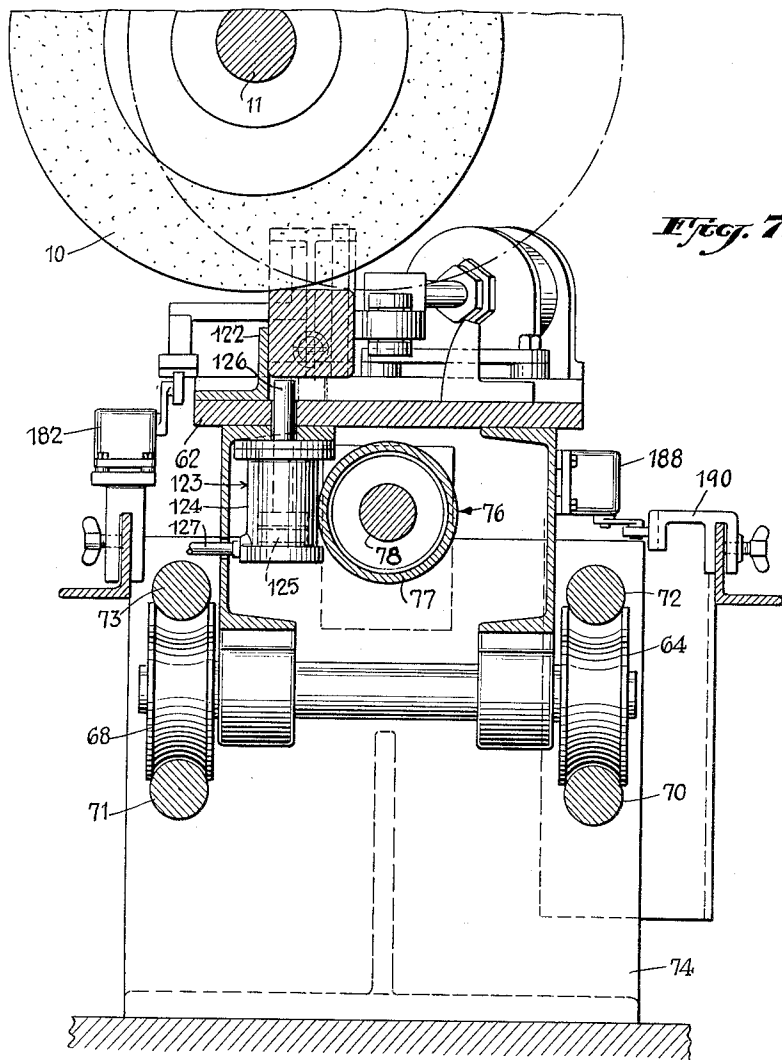
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BILLET GRINDER

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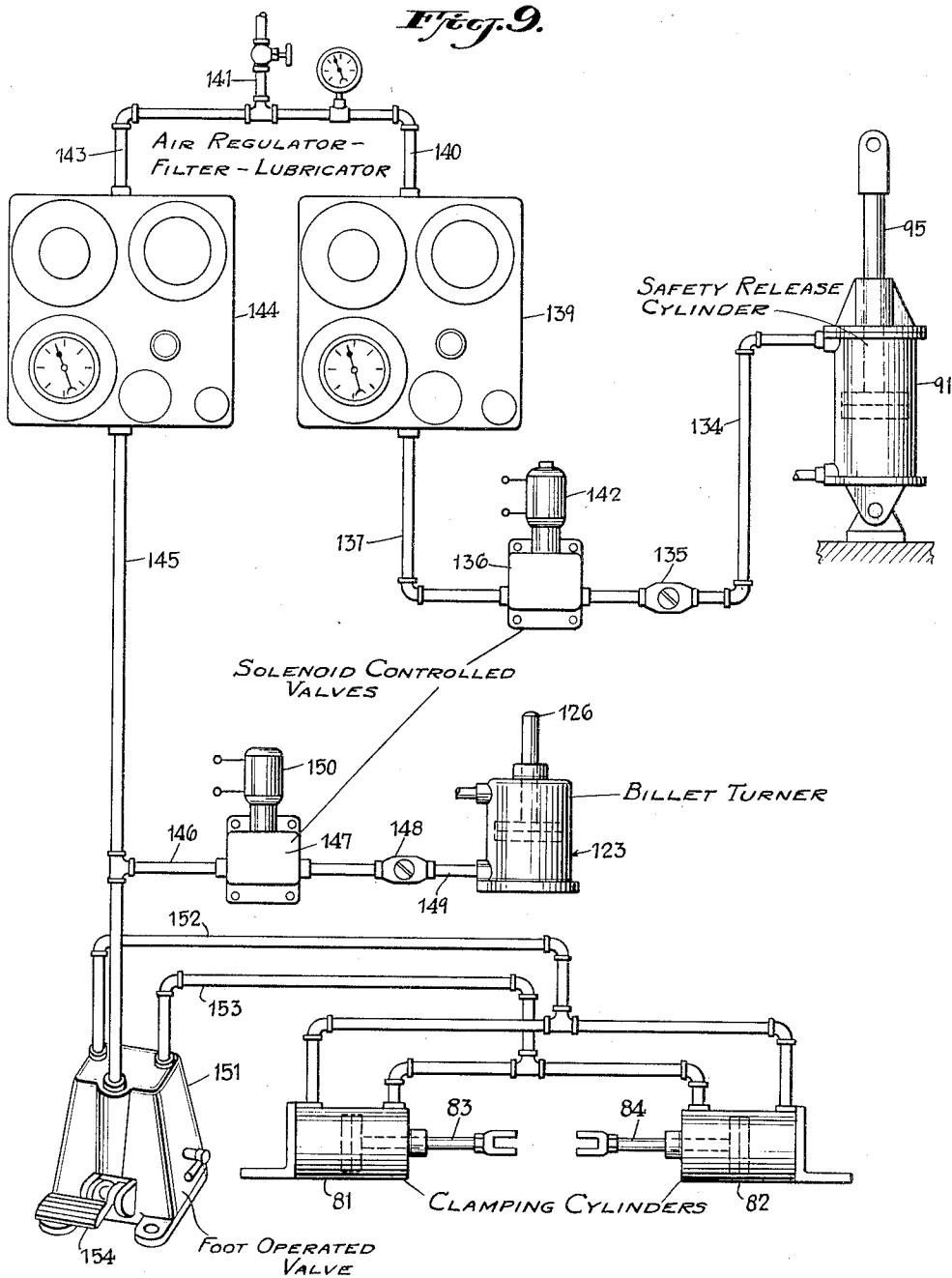
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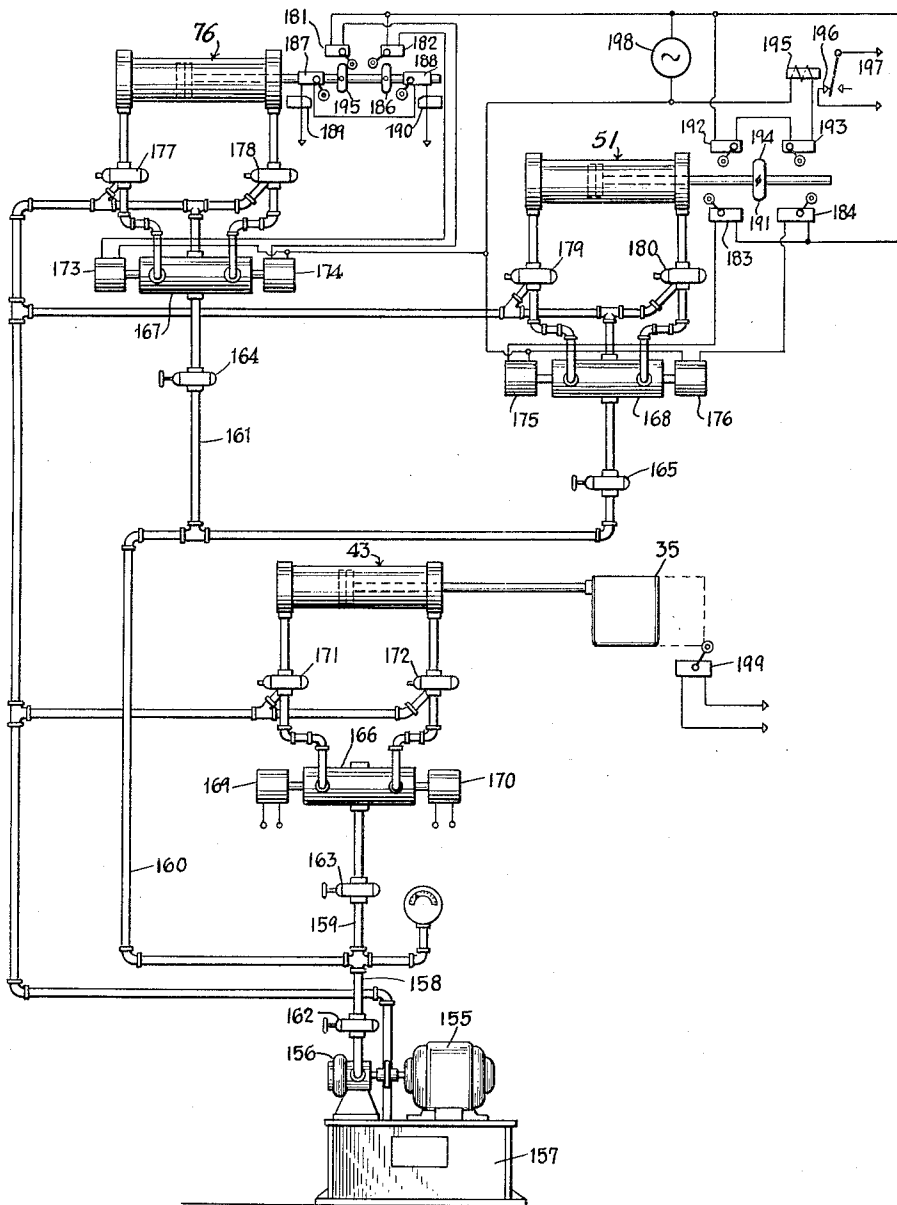
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*Fig. 10.*



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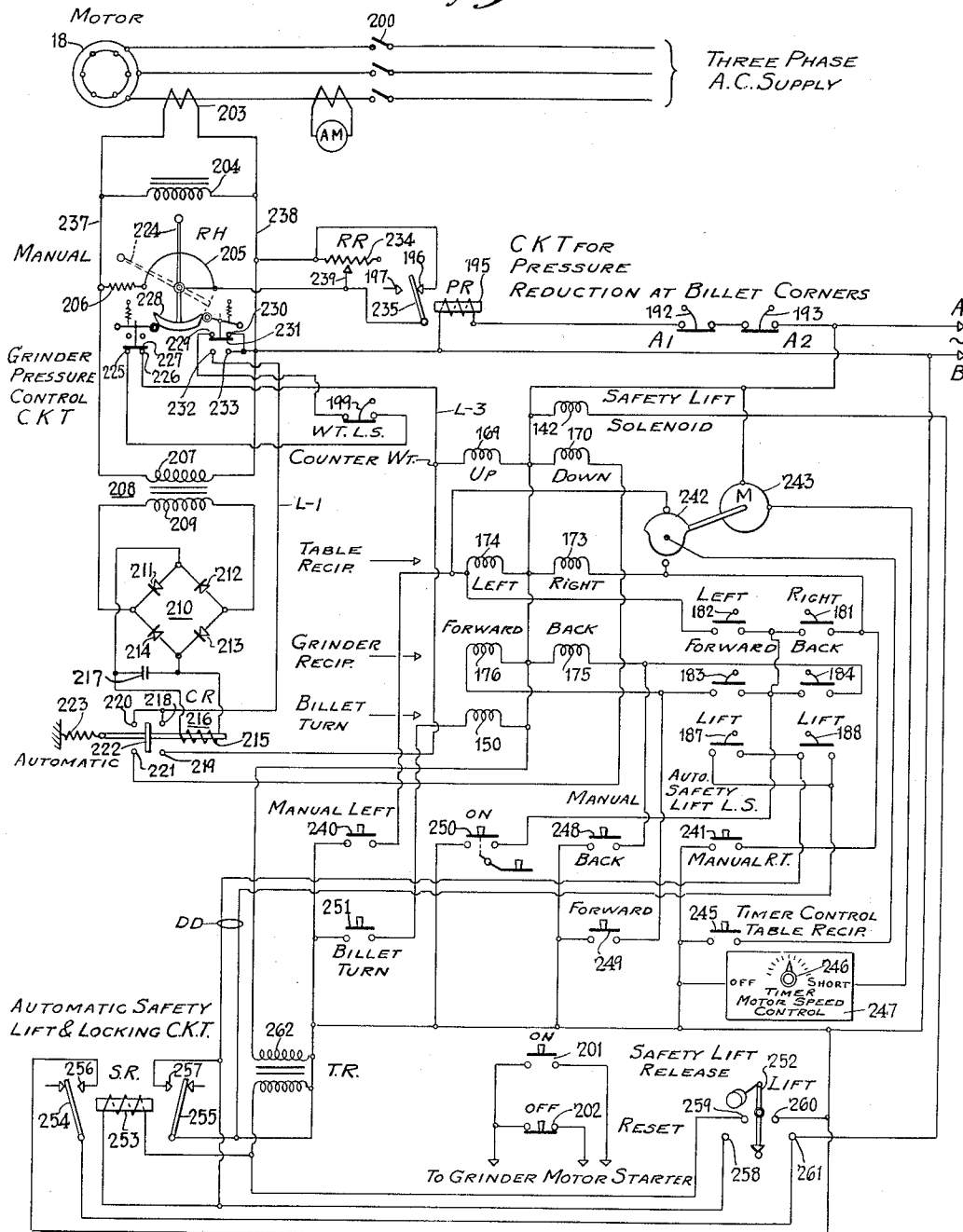
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*Fig. 11.*



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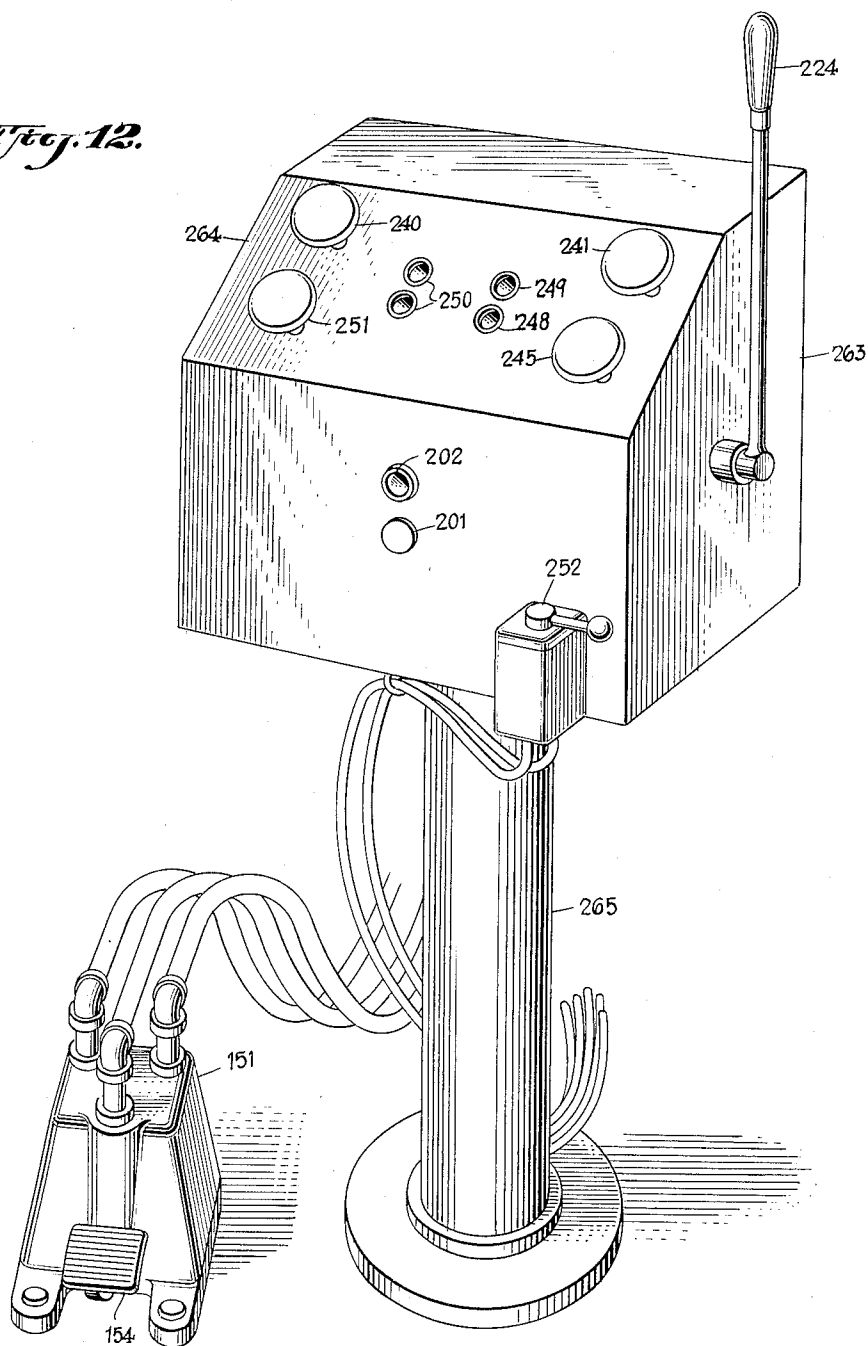
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*Fig. 12.*



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2,726,490

## BILLET GRINDER

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Application April 1, 1952, Serial No. 279,789

24 Claims. (Cl. 51—45)

This invention relates to apparatus for automatically grinding surfaces of metal billets such as, for example, rolled or forged steel billets.

This application is a continuation-in-part of my co-pending application Serial No. 253,242, filed October 26, 1951 and entitled "Billet Grinder."

Rolled or forged steel billets have, in an intermediate stage in their manufacture, relatively rough and uneven surfaces as a result of a rolling, hammer-forging or cogging operation, and for removing decarburized surface and minor surface imperfections, such as irregularities, slivers and small cracks and for providing a relatively smooth surface, free from imperfections, for subsequent rolling and forging operations, it has been the practice to surface grind these billets by manual or automatic grinding apparatus employing an abrasive grinding wheel which traverses the imperfect surfaces of the billets. In known types of manual and automatically controlled grinding apparatus of this type the grinding pressure has been controlled either manually or the pressure has been maintained constant irrespective of the load on the grinding wheel and hence the load on the motor or other device employed for driving the grinding wheel. Such arrangements are unsatisfactory not only because they produce uneven grinding, but also because a constant pressure on the grinding wheel may cause the grinding wheel to cut the surface of the billet either too rapidly or too slowly. This is particularly true when the characteristics of the surface of the billet vary across the face of the billet.

Also, in known types of automatic or semi-automatic billet grinding apparatus it has been customary to move the grinding wheel rapidly transversely across the surface of the billet as the billet is moved slowly in the direction of the longitudinal axis of the billet. It has been found that with this relationship between the movement of the billet and the grinding wheel, relatively high temperatures develop at the point of contact of the wheel with the billet because there is a relatively short period of time between the time that the grinding wheel contacts one spot on the billet and the next adjacent spot on the surface of the billet. This produces overheating of the billet with resulting surface decarburization, etc.

Furthermore, in connection with known types of automatic machines the mechanism which is reciprocated with the grinding wheel has been relatively heavy and complicated both because it was necessary to reciprocate the grinding wheel at a rapid rate and because of the equipment heretofore employed for forcing the grinding wheel against a billet.

It is an object of the present invention to provide an automatic grinding machine which does not have the disadvantages mentioned above and which is simple and economical to manufacture and operate.

In accordance with the preferred embodiment of the present invention, a pivotally mounted beam is provided which has a grinding wheel and its driving motor mounted on one side of the pivot point thereof. A counter-weight whose position is adjustable along the length of the beam

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is provided on the opposite side of the pivot point and the position of the counter-weight along the length of the beam is controlled by the energy consumed by the motor and hence by the motor load. The motor load is, of course, proportional to the load on the grinding wheel and therefore is related to the rate at which material is removed from the surface of the billet. As the load on the wheel, and hence on the motor, increases due to changes in the characteristics of the surface of the billet, the counter-weight is moved away from the pivot point and the pressure on the grinding wheel is decreased to compensate for the changes in surface characteristics. Conversely, as the load on the wheel tends to decrease, the counter-weight is moved toward the pivot point so that the pressure on the wheel is increased. Thus, the pressure of the grinding wheel against the billet is not constant but, instead, it is variable so that the load on the grinding wheel is maintained at a substantially constant value.

Also, in the preferred embodiment of the invention, the billet to be ground is mounted on a table which moves back and forth rapidly along a path which is parallel to the longitudinal axis of the billet. At the same time, the grinding wheel is moved slowly in a direction transverse to the longitudinal axis of the billet. Thus, over the major portion of the surface of a billet there is a relatively longer period of time between the times that the grinding wheel is operating on a first surface and then on an adjacent surface, and a greater area on the billet is ground between each reversal of the table than when the grinding wheel is moved back and forth rapidly and the table is moved slowly.

Because the grinding wheel moves transversely of the longitudinal axis of the billet at a comparatively slow rate and because of the arrangement provided for the control of the load on the grinding wheel, it is possible to mount only a relatively small number of parts on the pivoted beam and to provide relatively small and simple apparatus for reciprocating the beam. Accordingly, a further feature of my invention is the simplicity of the structure and the apparatus required for reciprocating the grinding wheel.

In accordance with a further feature of my invention, I provide controls for producing a short stroke reciprocation of the billet-carrying table at any position of the grinding wheel on the surface of the billet. This feature is provided to permit extra grinding of portions of the billet surface which require such grinding without hand operation of the grinding wheel and without traversing the entire length of the billet.

Also, I provide a pair of pivotally and slidably mounted clamping arms for clamping the billet at both its ends and one side. The clamping arms are operated by a pair of fluid actuated cylinder and piston means which also set the positions of the table reciprocation controls and hence the length of table reciprocation stroke is controlled in accordance with the length of a billet being ground.

In addition to the above features, the preferred embodiment of my invention includes a quick-acting, air actuated cylinder and piston means for lifting the grinding wheel in the event that it passes beyond the end of a billet and controls for reducing the pressure of the grinding wheel on the billet as it approaches the corners thereof to prevent thereby undesirable rounding of the corners.

Other objects and advantages of the invention will more fully appear from the following detailed description setting forth the manner in which I now prefer to practice the invention and from the accompanying drawings in which:

Fig. 1 is a side elevation view of the preferred embodiment of my invention;

Fig. 2 is a plan view of the embodiment shown in Fig. 1;

Fig. 3 is a front elevation view of the preferred embodiment of the invention shown in Figs. 1 and 2;

Fig. 4 is a side elevation view of the embodiment shown in the preceding figures taken from the opposite side from the view in Fig. 1;

Fig. 5 is a fragmentary, plan view of the embodiment of the preceding figures and shows the billet table clamping devices more clearly;

Fig. 6 is a plan view showing a portion of the billet table illustrated in Fig. 5 and shows the positions of the billet clamping devices when a billet is released and turned;

Fig. 7 is an enlarged, fragmentary, cross-sectional view of the billet table shown in the preceding figures and is taken along the line designated by the numerals 7—7 in Fig. 3;

Fig. 8 is an enlarged, fragmentary, cross-sectional view of the grinding wheel and its mounting shown in the preceding figures and is taken along the line 8—8 in Fig. 1;

Fig. 9 is a schematic diagram illustrating the system employed in the preferred embodiment of the invention for clamping and turning a billet and for lifting the grinding wheel;

Fig. 10 is a schematic diagram illustrating the system employed in the preferred embodiment of the invention for reciprocating a billet and the grinding wheel and for controlling the load on the grinding wheel;

Fig. 11 is an electric circuit diagram showing the electrical circuits which may be employed for controlling the grinding apparatus of my invention; and

Fig. 12 is a perspective view of a preferred mounting arrangement for the manual controls for controlling the operation of the grinding apparatus of my invention.

Referring to Figs. 1—4 which show, respectively, side elevation, plan, front elevation and side elevation views of the preferred embodiment of my invention, it will be seen that a grinding wheel 10 is mounted on a rotatable shaft 11 which is mounted on a pair of bearings 12 and 13 which are supported on the end of a beam 14. The grinding wheel 10 is rotated on the shaft 11 by a pulley 15 which is drivingly connected by means of belts 16 and a pulley 17 to an electric motor 18.

The motor 18 is secured to a platform 19 which is fastened to the beam 14 at a point thereon spaced from the pivot point of the beam 14. The beam 14 is pivotally mounted on a frame 20 by means of a shaft 21 which is mounted in bearings 22 and 23. As shown more clearly in Fig. 2, the shaft 21 is secured to the beam 14 by means of pins 24 and 25 which pass through collars 26 and 27, the collars 26 and 27 being welded to plates 28 and 29 which in turn are welded to the beam 14. Although shaft 21 may be a smooth-ended shaft fitted into smooth annular bearings, it preferably is threaded at each end and is screwed into the bearings 22 and 23 which may be the nuts shown. This construction is preferred because it provides a larger bearing surface for a given length, and it has been found to be most satisfactory for the purposes of my invention because it also assists in maintaining the positions of the bearings 22 and 23.

The bearings 22 and 23 are mounted on a pair of bearings 30 and 31 which are slidably mounted on a pair of shafts 32 and 33 whose axes are parallel to each other. The shafts 32 and 33 are secured to the frame 20 by bolts 34.

It will be noted from the drawings that the grinding wheel 10 and its associated driving motor 18 are both mounted on the same side of the pivot shaft 21 and therefore their weight tends to press the beam 14 downward at the side of the pivot shaft 21 on which the wheel and motor are mounted. A movable counter-weight 35 and a fixed counter-weight 36 are provided on the opposite side of the shaft 21 so as to counter-balance the weight of the wheel 10 and the motor 18. As will be

seen in Figs. 1, 2 and 4, the counter-weight 35 is suspended from the beam 14 by brackets 37 and 38 which engage the axles of flanged wheels 39, 40, 41 and 42.

The counter-weight 35 is adjusted along the beam 14 by fluid actuated cylinder and piston means 43 which comprises a cylinder 44 and a piston 45 and which is mounted on the underside of the beam 14. The cylinder 44 is secured to the beam 14 in any suitable manner, such as by a bracket 46, and the piston rod 47 is connected to the counter-weight 35 by a pivotal coupling 48. The cylinder has a pair of flexible fluid lines 49 and 50 for the purpose of admitting fluid to the cylinder and thereby moving the piston rod 47 in either of two directions.

The beam 14 is reciprocated on the shafts 32 and 33 by fluid actuated cylinder and piston means 51 comprising a cylinder 52 and a piston 53. The cylinder 52 is secured to the frame 20 by means of a bracket 54 and a pin 55 passing through an extension 56 on the cylinder 52. The piston 53 is connected to a piston rod 57 which is fastened to an angle bracket 58 by means of a nut 59 threaded on the end thereof. The bracket 58 is bolted or otherwise secured to the plate 60 which supports the bearing 23 on the bearing 31.

A billet to be ground such as billet 61 is mounted on a table 62 which is supported on grooved wheels 63—69 which travel on rails 70 and 71 in the form of steel rods. The grooved wheels 63—69 are also guided by a pair of guide rods 72 and 73 mounted above the rails 70 and 71 and extending parallel thereto. The rails 70 and 71 and the guide rods 72 and 73 are mounted on a frame 74 and are held thereon by means of nuts 75 threaded on the ends of the rails and rods. Fluid actuated cylinder and piston means 76 comprising a cylinder 77 mounted on the underside of the table 62 and a piston rod 78 connected thereto, is provided to move the table 62 back and forth in a direction parallel to the longitudinal axis of the billet 61. The piston rod 78 is connected at both ends thereof to the frame 74 by means of bolts 79 and 80 and the cylinder 77 is secured to the underside of the table 62. The cylinder 77 has a pair of flexible fluid lines (not shown) connected thereto for supplying fluid thereto and for thereby causing the cylinder 77 and hence the table 62 to move in either of two directions along the rails 70 and 71.

The billet 61 preferably is clamped on top of the table 62 by air actuated cylinder and piston means 81 and 82, each comprising a cylinder and a piston. The cylinder and piston means 81 and 82 have piston rods 83 and 84 with billet engaging members 85 and 86 attached thereto. Air under pressure is supplied to the cylinder and piston means 81 and 82 through the ports 87—90 to operate the rods 83 and 84. The operation and further details of the billet clamping devices will be set forth hereinafter.

A quick-operating, air actuated cylinder and piston means 91 is connected between the end of beam 14 and the foundation 92. One end of the means 91 is pivotally connected to a bracket 93 secured to the foundation 92 by a pin 94, and the piston rod 95 is connected to the end of the beam 14 by a yoke 96, a pin 97 and a bracket 98. Air under pressure is supplied to the means 91 through the port 99 and is exhausted from the means 91 through the port 100. When the grinding apparatus is in operation the cylinder and piston means 91 is inoperative; that is, it exerts substantially no force on the beam 14 and hence the pressure on the grinding wheel 10 is determined substantially by the position of the counterweight 35. However, in the event that it is desired to lift the grinding wheel 10 quickly either from the billet 61 or because the wheel has overrun the billet, then air under pressure is supplied to the means 91 through the port 99, and the end of the beam 14 to which the rod 95 is attached is moved downwardly.

A handle 101 may be attached to the end of the extension 14a of the beam 14 for the purpose of manually

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adjusting the position of the grinding wheel 10 when automatic operation is not desired. The grinding wheel 10 may also be covered with a hood 102 to provide protection for an operator.

An exhaust fan 103 having a flexible tube 104 which terminates in a hood 105 may be provided for removal of the particles and dust produced by the grinding wheel 10 during the grinding operation.

Referring to Figs. 2, 5 and 6, it will be seen that the cylinder and piston means 81 and 82 are mounted on plates 114 and 115 secured to the table 62 so that the axes of the piston rods 83 and 84 intersect the axis of the billet 61 at an acute angle. The rods 83 and 84 are pivotally connected to the billet engaging members 85 and 86 by means of yokes 106 and 107 and pins 108 and 109 so that the members 85 and 86 can pivot with respect to the rods 83 and 84. The billet-engaging members 85 and 86 are also pivotally mounted at one end on slidable end clamps 110 and 111 and they carry at the opposite ends rollers 112 and 113 which engage the side of the billet 61.

The end clamps 110 and 111 slide in slots provided in the mounting plates 114 and 115 and they are urged away from the billet 61 by springs 116 and 117, which are secured to the mounting plates 114 and 115 by the threaded bolts 118 and 119 and the brackets 120 and 121.

When the piston rods 83 and 84 are drawn away from the billet 61 by the cylinder and piston means 81 and 82, the end clamps 110 and 111 move away from the billet 61 because of the action of the springs 116 and 117 and, in addition, the billet-engaging members 85 and 86 move away from the billet 61 and pivot to the positions shown in Fig. 6. Thus, the billet 61 is completely free and may be rotated or may be removed from the table 62. However, when the piston rods 83 and 84 are moved toward the billet 61 by the cylinder and piston means 81 and 82, the members 85 and 86 first pivot until the rollers 112 and 113 are in contact with the side of the billet 61. Then, as the rods 83 and 84 continue to move toward the billet 61, the rollers 112 and 113 rotate and move along the length of the billet 61 and the end clamps 110 and 111 move against the ends of the billet 61. In this manner, the billet 61 is clamped both at its ends and at its sides, the billet-engaging members 85 and 86 forcing the billet 61 against a stop 122 which may take the shape of an angle bracket extending almost the full length of the billet 61. The pressure which the rollers 112 and 113 exert against the side of the billet 61 before the billet is clamped at its ends by the end clamps 110 and 111 may be adjusted by adjustment of the threaded bolts 118 and 119 which control the forces exerted by the springs 116 and 117 on the end clamps 110 and 111.

In the preferred embodiment of the invention the grinding apparatus is also provided with power-operated billet turning equipment. Referring particularly to Figs. 5, 6 and 7, it will be seen that a fluid actuated cylinder and piston means 123 comprising a cylinder 124 and a piston 125 is mounted on the under side of the table 62. A turning finger 126 is secured to the piston 125 so that when fluid such as air is introduced into the cylinder 124 through the line 127 the finger 126 moves upwardly and engages the billet 61 on the under side thereof at a point in front of its center of gravity. If the billet 61 has been released by the end clamps 110 and 111 and the billet-engaging members 85 and 86, the finger 126 will, as it continues to move in the upward direction, tilt the billet 61 into such a position that it finally falls on the side which was previously engaged by the rollers 112 and 113. Movement of the billet 61 away from the stop member 122 is limited by the stop member 128, and the position of the billet 61 after it has been turned through 90 degrees is indicated in Fig. 6. Subsequent operation of the clamping cylinder and piston means 81 and 82 pushes the billet 61 into engagement with the stop member 122, in which position it is ready for grinding on a new surface. Similar

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billet turning apparatus is described in my copending application Serial No. 231,097, filed June 12, 1951 and entitled "Billet Grinder," now abandoned.

In the preferred form of the invention the grinding wheel 10 is mounted so that it may be removed without removing the shaft 11 on which it is mounted and without disconnecting the shaft 11 from the motor 18. Referring to Fig. 8, it will be seen that the grinding wheel 10 is mounted on a pair of flanges 128 and 129 which are pressed together and against the grinding wheel 10 by a nut 130 threaded on the end of the shaft 11, the flange 128 being held in its proper position on the shaft 11 and caused to rotate therewith by a pair of tapered bushings 131 and 132. The tapered bushing 132 is keyed to the shaft 11. When it is necessary to remove the grinding wheel 10, it may be removed readily by the mere unscrewing of nut 130 and removal of washer 133 and flange 129, the cover 102 also being removed if desired or required by the size of the grinding wheel 10.

The various fluid actuated cylinder and piston means mentioned above may be actuated by air or by a liquid, such as oil, under pressure. In the preferred form of the invention the cylinder and piston means employed for the reciprocation of the table 62, the beam 14 and the counterweight 35 are actuated by oil under pressure, and the cylinder and piston means employed for the rapid lifting of the grinding wheel 10, the turning of the billet 61 and the clamping of the billet 61 are actuated by air, air being preferred for the operation of these cylinders and piston means because of the speed and cushioning effect obtainable.

Fig. 9 illustrates schematically the controls and connections for the air actuated cylinder and piston means. In this figure it will be seen that the air under pressure for operation of the safety release or grinding wheel lifting cylinder and piston means 91 is supplied thereto through a line 134 after passing through an air flow regulator 135, a solenoid controlled valve 136, line 137, an air pressure regulator and filter 139, line 140 and line 141, the last-mentioned line being connected to a source of air under pressure. Thus, when solenoid 142 is actuated by controls to be described hereinafter, air is admitted into the upper portion of the cylinder and piston means 91 causing the piston rod 95 to move rapidly downward, and when the solenoid 142 is de-energized, the piston rod 95 is released and assumes a position determined by the position of the counterweight 35 on the beam 14.

Air under pressure is supplied to the billet turning cylinder and piston means 123 through the line 143, an air pressure regulator and filter 144, line 145, line 146, a solenoid actuated valve 147, an air flow regulator 148 and line 149. When the solenoid 150 is suitably energized, air flows into the lower part of the cylinder and piston means 123 and causes the billet turning finger 126 to move upwardly, and when the solenoid 150 is de-energized, the supply of air to the means 123 is cut off and the finger 126 drops below the top of table 62.

Clamping cylinder and piston means 81 and 82 are double acting and preferably are controlled through a foot-operated valve shown schematically at 151. Air under pressure and supplied by line 145 is diverted to either line 152 or 153, as required, by the valve 151 causing the rods 83 and 84 to move outwardly from or inwardly to the cylinders, depending upon whether the air is diverted to line 152 or line 153, respectively. Preferably, valve 151 is of the type which upon one depression of the foot lever 154 causes the air to be diverted into one of the lines 152 and 153 and upon the next depression of the lever 154 causes the air to be diverted into the other of the lines 152 and 153.

In Fig. 10 there is shown schematically the oil operated cylinder and piston means and their connections both with the valves which produce operation thereof and the electrical controls which are operated thereby. Referring to Fig. 10, oil is supplied under pressure by a motor 155

and a pump 156 from a reservoir 157. The oil is conveyed to the cylinder and piston means over the lines 158, 159, 160 and 161, line 158 being provided with a pressure relief valve 162 and lines 159, 160 and 161 being provided with shut-off valves 163, 164 and 165. The supply of fluid to the cylinder and piston means 43, 76 and 51 is controlled respectively by electrically operable valves 166, 167 and 168. The valve 166 is provided with a pair of solenoids 169 and 170 which operate the valve, and pressure relief valves 171 and 172 are connected between valve 166 and cylinder and piston means 43. The valves 167 and 168 are also equipped with pairs of solenoids 173—174 and 175—176, and pressure relief valves 177, 178, 179 and 180 are connected in the lines between the valves 167 and 168 and the cylinders 51 and 76.

The solenoids 169 and 170 of valve 166 are controlled by the circuit shown in Fig. 11 and described in connection therewith, and the valves 167 and 168 are controlled respectively by the limit switches 181—182 mounted on the frame 74 to the rear of table 62 (see Figs. 1, 4 and 5) and 183—184 mounted on the frame 20 to the left of the beam 14 (see Figs. 1 and 2). Limit switches 181 and 182 are actuated by a pair of stops 185 and 186 which are carried by the end clamps 110 and 111, as is best shown in Fig. 5, and safety lift switches 187 and 188 are controlled by a pair of adjustable stops 189 and 190, these latter stops being mounted on the stationary frame 74 which supports the table 62 (see Figs. 2 and 5). As will be described hereinafter in greater detail, safety lift switches 187 and 188 control the operation of the safety release or lift cylinder 91 and are mounted on the front of the table 62 (see Figs. 3 and 5).

Limit switches 183 and 184 are operated by a stop 191 which may take the form of a V-shaped plate, shown more clearly in Figs. 1 and 2. Switches 192 and 193 are also mounted on the frame 20 to the right of the beam 14, as indicated in Figs. 2 and 4, and are operated by a cam 194 also shown in Figs. 2 and 4. These switches 192 and 193 are employed in connection with relay 195 to reduce the pressure on the grinding wheel 10 before the wheel reaches the corners of the billet 61 and their operation will be described in greater detail in connection with Fig. 11. Relay 195 has contacts 196 and 197 and is connected in series with the switches 192 and 193 and the source 198.

A limit switch 199 is mounted on the end of beam 14, as it best shown in Fig. 4, and is engageable with the bracket 37 which supports the counter-weight 35 so as to de-energize the solenoid 159 when the counter-weight 35 is at its rearmost position.

Referring to Fig. 11, which is an electrical circuit diagram of the electrical system employed for controlling the grinding apparatus of my invention, it will be seen that the motor 18 is connected to a three-phase source through contacts 200 which are controlled by the manually operable switches 201 and 202. In accordance with one feature of my invention, the force applied to the grinding wheel 10 to hold it against the billet 61 is automatically adjusted in accordance with the load on the grinding wheel 10. To accomplish this, I employ the circuit shown in the upper left-hand side of Fig. 11. A transformer 203, which may be, for example, a current transformer, is coupled to the input circuit of the motor 18 and when the motor 18 is in operation voltage is produced across the secondary of the transformer 203 which is shunted by a reactance 204, a manually variable resistor 205 in series with a fixed resistor 206 and the primary 207 of the transformer 208. The secondary 209 of the transformer 208 is connected to diagonally opposite points on a bridge rectifier 210 which comprises dry rectifiers 211, 212, 213 and 214, which may, for example, be selenium or copper oxide rectifiers. The output of the bridge rectifier 210 is connected to the energizing coil 215 of a three-position relay 216 which

may be shunted by a filter condenser 217. This relay 216 has two pairs of contacts 218—219 and 220—221 and an armature 222. The armature 222 is connected to an adjustable spring 223 which causes the armature 222 to connect the contacts 220 and 221 unless the coil 215 is energized to at least a predetermined extent by the rectifier 210. Thus, when only a small current is flowing through the coil 215, the contacts 220 and 221 are connected together by the armature 222, but when the current exceeds a predetermined level, determined by the sensitivity of the relay 216 and the tension on the spring 223, contacts 220 and 221 are disconnected. As the current through coil 215 is further increased, the armature 222 moves toward the contacts 218 and 219 until finally when a second predetermined current level is reached the contacts 218 and 219 are connected together.

When the handle 224 of the variable resistor 205 is in the vertical position shown, the contacts 225 and 226 are connected together by the contactor 227 which is moved into its downward position by the actuator 228 on the end of the handle 224 and the contacts 229 and 230 are connected together by the contactor 231, but when the handle 224 is moved from the vertical position shown to some position such as the one shown in dotted lines the contacts 225 and 226 are disconnected and the contacts 232 and 233 are connected together by the contactor 231. In the vertical position of the handle 224 the automatic operation of the grinding apparatus is discontinued and the grinding wheel 10 is completely lifted off the billet 61, but when automatic operation is desired, the handle 224 is moved from the vertical position and the contacts 218 and 220 are connected to terminal B of the power source.

Contact 219 is connected to one end of the solenoid or coil 169 employed to actuate the valve 166 and the opposite end of solenoid 169 is connected to terminal A. Also, contact 221 is connected to one end of solenoid or coil 170 which operates the valve 166 in the opposite direction and the other end of solenoid 170 is connected to the terminal A. Thus, when contacts 218 and 219 are connected together by the armature 222, a circuit for the solenoid 169 which actuates the valve 166 in such a direction that the counter-weight 35 is moved rearwardly of the beam 14, and hence in such a direction that the force on the grinding wheel 10 is decreased, is established from terminal B of the power source through contacts 232 and 233, contactor 231, contacts 218 and 219, solenoid 169 and back to terminal A. However, when contacts 220 and 221 are connected together by armature 222, a circuit is completed for energizing solenoid 170 (which moves the counter-weight 35 toward the grinding wheel 10) from terminal B through contacts 232 and 233, contactor 231, contacts 220 and 221, solenoid 170 and back to terminal A. When the armature 222 is in a position intermediate the contacts 220—221 and 218—219, neither of the pairs of contacts is connected together and hence neither of the solenoids 169 and 170 is energized. When neither solenoid 169 and 170 is energized, the counter-weight 35 remains in a fixed position.

Since the current in coil 215 varies with the current in the input circuit of the motor 18, the position of the counter-weight 35 is controlled by the current in the input circuit of motor 18 and hence by the energy consumed by the motor 18. Consequently, when the input current to the motor 18 is increased above a predetermined value because of an increase in the load on the grinding wheel 10, the valve 166 is operated so that the counter-weight 35 moves away from the grinding wheel 10. Also, when the input current to the motor 18 decreases below a predetermined value because of a decrease in the load on the grinding wheel 10, the valve 166 is operated so that the counter-weight moves toward the grinding wheel 10. In this manner, the load on the

motor 18, and hence the rate at which material is removed from the billet 61, and the load on the grinding wheel 10 may be maintained at a substantially constant value.

The value of the load on the motor 18 may be adjusted by adjustment of the spring 223 and by adjustment of the position of the handle 224. Adjustment of the handle 224 changes the value of the resistor 205 in series with the resistor 206 and hence changes the voltage at the primary 207 at the transformer 208. Thus, if the handle 224 is moved to the position shown in dotted lines, the value of the resistor 205 is decreased and the voltage at the primary winding 207 is correspondingly decreased. When the handle 224 is in the vertical position shown, the resistor 205 has its maximum value and hence the voltage at the primary winding 207 is at its maximum value. The current in the coil 215 changes with and in the same direction as the voltage across the primary winding 207.

In accordance with a further feature of the invention, the downward force on the grinding wheel 10 is reduced as the grinding wheel 10 approaches the forward and rear corners of the billet 61. This feature is desirable not only because it prevents sudden dropping of the grinding wheel if it goes over the front and rear corners of the billet 61, but also because it reduces rounding of these corners of the billet. Adjustable resistor 234, relay 195 and its associated armature 235 and contact 196 and switches 192 and 193 are provided to accomplish this control of the force on the grinding wheel 10.

Referring to Fig. 4, the switches 192 and 193 which are adjustably mounted on the frame 20 are adjusted to such positions that switch 192 is operated by cam 194 when the billet contacting surface of the grinding wheel 10 is close to the forward edge of the billet 61 and the switch 193 is operated by the cam 194 when the billet contacting surface of the grinding wheel 10 is close to the rear corner of the billet 61. Referring again to Fig. 11, the relay 195 normally is energized by a circuit which may be traced from terminal A through switches 192 and 193, through the coil of relay 195 and back to terminal B. When the relay 195 is energized, the armature 235 is pulled up against contact 196 and hence the resistor 234 is shorted out. With resistor 234 shorted out, the voltage at the primary winding 207 is determined by the setting of handle 224 and resistor 206 and hence the downward force on the grinding wheel 10 is determined by the setting of the handle 224. However, when either of the switches 192 and 193 is operated by the cam 194, the energizing circuit for relay 195 is broken and the armature 235 falls back against contact 197. The resistance then appearing between the leads 237 and 238 is increased by the value of the resistance 234. Because of the increase of resistance between leads 237 and 238 a larger voltage will appear across the primary 207 than when the resistor 234 is shorted out. A larger voltage across the primary 207 produces a larger current in the coil 215 and pulls armature 222 against contacts 218 and 219 closing the circuit for the solenoid 169 which, as explained previously, moves the counter-weight 35 rearwardly away from the grinding wheel 10 and reduces the downward force on the grinding wheel 10. As soon as the counter-weight 35 has moved rearwardly enough to reduce the downward force on the grinding wheel 10, and hence the input current to the motor 18, an amount sufficient to compensate for the increase in current produced in coil 215 by the insertion of the resistor 234 in series with resistors 205 and 206, the armature 222 will resume its intermediate position and the counter-weight 35 will stop. It is thus apparent that when either of the switches 192 and 193 is operated, the downward force on the grinding wheel 10 is decreased and the amount of decrease is determined by the setting of control 239 for resistor 234.

It will also be apparent from a consideration of the

above and from an examination of the circuit diagram in Fig. 11 that the downward force on the grinding wheel 10 may be manually adjusted at any time during the operation of the grinding apparatus by movement of the handle 224. In its position nearest the horizontal, the handle will cause the wheel 10 to press with maximum force against the billet 61 and, as the handle 224 is moved toward the vertical position shown in solid lines, the downward force is decreased until in some position just prior to the vertical position the minimum force which it is possible to obtain with an automatic control circuit is applied to the grinding wheel 10. However, the circuit shown is so arranged that by motion of the handle 224 into its vertical position the counter-weight 35 is moved to the rear end of the beam 14. When the counter-weight 35 is at the rear end of the beam 14, the wheel 10 is completely lifted from the billet 61, and normally the grinding wheel is in this position when the grinding apparatus is idle. Therefore, it is desirable that when the counter-weight 35 is in its rearmost position, the solenoid 169 is de-energized. To accomplish this result the arm 228 on the handle 224 moves contactor 227 against contacts 225 and 226, connecting contacts 225 and 226 together, and the arm 228 permits the contactor 231 to connect contacts 229 and 230 together. Thus, a circuit may be traced from terminal B through contacts 229 and 230, contactor 231, switch 199, contacts 225 and 226, contactor 227, solenoid 169 and back to terminal A, and when the handle 224 is first moved to the vertical position, the solenoid 169 is energized causing the counter-weight 35 to move rearwardly along the beam 14. However, when the counter-weight 35 reaches its rearmost position, it operates switch 199 and opens the last-mentioned energizing circuit for solenoid 169. The counter-weight 35 remains in the rearmost position until the handle 224 is again moved from its vertical position and places the counter-weight 35 under the automatic control circuit previously described.

Solenoids 173 and 174 which control the operation of valve 167, and hence the reciprocation of the table 62, may be energized through manually operable switches 240 and 241, through contactor 242 rotatable by motor 243 and through the table controlled switches 181 and 182. Switches 240 and 241 are provided in the event that it is desired to control the reciprocation of the table 62 manually and the switches 181 and 182 are provided for automatic control of the table reciprocation. Referring to Fig. 5, it will be seen that the switches 181 and 182 are adjustably mounted on the frame 74 and are engageable with cams 185 and 186 which are mounted on the end clamps 110 and 111. By the mounting of the cams 185 and 186 on the end clamps, they are moved with the end clamps and hence they always operate the switches 181 and 182 when the wheel 10 reaches the end of a billet, even though different billets may have small differences in length. Switch 181 is mounted on the frame 74 in such a position that it is operated when the end of the billet 61 adjacent the end clamp 110 is under approximately the center of the face of the grinding wheel 10, and the switch 182 is mounted on the frame 74 in such a position that it is operated by the cam 186 when the end of the billet 61 adjacent the end clamp 111 is under the center of the face of the grinding wheel 10. Thus, when the grinding wheel 10 reaches an end of the billet 61, one of the two switches 181 and 182 is operated and energizes the corresponding solenoid 173 or 174 causing the table 62 to reverse its direction of movement.

If there is a portion of the surface of the billet 61 which requires additional grinding, a relatively short reciprocatory stroke of the table may be provided by operation of the timer control switch 245 and the control 246 on the timer motor speed control apparatus 247, the latter apparatus being connected to the motor 243 and used to control the speed thereof. Operation

of the switch 245 supplies electrical energy to the contactor 242 which alternately energizes solenoids 173 and 174 and the speed of the motor 243 as adjusted by the control 246 determines the times at which solenoids 173 and 174 are alternately energized and hence the length of the path of movement of the table 62.

Switches 248 and 249 are provided for manual control of the reciprocation of the beam 14, and switches 183 and 184, as indicated previously, provide automatic control of the reciprocation of the beam 14. Referring to Fig. 1, it will be seen that switches 183 and 184 are mounted on the frame 20 and are so positioned with respect to the cam 191 that switch 184 is operated when the portion of the face of the wheel 10 which contacts the billet 61 is at the forward corner of the billet 61 and that the switch 183 is operated by the cam 191 when the face of the wheel 10 which contacts the billet 61 is at the rear corner of the billet 61. Thus, as the contacting portion of the wheel 10 reaches the forward corner of the billet 61, the direction of motion of the beam 14 is reversed and, when the contacting surface reaches the rear corner of the billet 61, the direction of motion of the beam 14 is again reversed. The positions of the switches 183 and 184 may be adjusted so as to accommodate billets of different width.

A manually operable switch 250 is provided so that switches 181, 182, 183 and 184 may be disabled when it is desired to stop the automatic reciprocation of the beam 14 and the table 62. With switch 250 in its "off" position the manual switches 246, 241, 248 and 249 may be employed to position the beam 14 or the table 62.

The billet turning solenoid or coil 150 may be energized by operation of the manually operable switch 251, and when operated, the billet turning finger 125 engages and lifts the billet 61 as previously described.

The safety lift solenoid or coil 142 may be energized by the switches 187 and 188 which are mounted on the front of the table 62 (see Fig. 5) and it may be energized by the manually operable switch 252. Switches 187 and 188 are provided so that if the wheel 10 passes beyond the end of a billet one of the switches 187 and 188 is operated and energizes relay 253 which has armatures 254 and 255 and contacts 256 and 257. When relay 253 is energized it pulls armature 254 against contact 256 and armature 255 against contact 257. Engagement of the armature 255 with the contact 257 closes an energizing circuit for the relay 253 and keeps the relay 253 operated until the relay is reset by the switch 252, as indicated hereinafter. Armature 254, when pulled against the contact 256, closes an energizing circuit for the solenoid 142 and hence causes operation of the air actuated cylinder and piston means 91. As previously described, the air actuated cylinder and piston means 91 pulls the rear of the beam 14 downwardly and lifts the wheel 10 off the billet 61 and above the end clamps 110 and 111.

If one of the switches 187 and 188 is operated, the cylinder and piston means 91 remains operated as long as the relay 253 is energized. Because of the holding circuit through armature 255 and contact 257, the relay 253 remains energized until switch 252 is operated to its reset position in which the contacts 258 and 259 are connected together. When contacts 258 and 259 are connected together, the relay 253 is short-circuited and the armatures 254 and 255 fall back against their idle contacts.

If at any time it becomes necessary to lift the wheel 10 quickly from the billet 61, the manually operable switch 252 may be operated to its lift position so as to connect contacts 260 and 261 together. Operation of the switch 252 in this manner also energizes the safety lift solenoid 142 and actuates the cylinder and piston means 91. However, as soon as the switch 252 is returned to its intermediate or rest position, the solenoid

142 is deenergized and cylinder and piston means 91 becomes idle.

If desired, switches 187 and 188, or additional switches connected in the same manner as these switches, may be mounted on the frame 20 and operated by a cam carried by the reciprocating means for beam 14 so as to lift the wheel 10 if the wheel 10 passes beyond a corner of the billet 61.

Transformer 262 is provided for the purpose of supplying the required voltage to the relay 253 and may be omitted if a relay operating at the voltage of the source connected to terminals A—B is employed.

Fig. 12 illustrates the preferred arrangement of the manually operable controls employed in connection with the grinding apparatus of my invention. In this figure, the handle 224 which controls the grinding wheel pressure is mounted on the side of a cabinet 263 which houses the various manual switches. The grinding motor control switches 201 and 202 and the safety lift cylinder and piston means operating and reset switch 252 may be mounted on the front of the cabinet 263.

The cabinet 263 is provided with a sloping panel 264 on which the manual table reciprocation control switches 240 and 241, the billet turning switch 251, the beam and table reciprocation "on-off" switch 250, the timer energizing switch 245 and the beam reciprocation control switches 248 and 249 are mounted.

The billet clamping control valve 151 may be separately mounted adjacent the pedestal 265 of the cabinet 263 so that all of the controls are within easy reach of an operator.

From the above it will be seen that when the appropriate switches are operated the table 62 is reciprocated along a path which is parallel to the axis of the grinding wheel 10 and the grinding wheel 10 is reciprocated crosswise of the table 62. The rate at which the table 62 and the beam 14 are reciprocated may be controlled by controlling the pressure of the fluid supplied to the cylinders 76 and 43 and by controlling the rate at which the fluid is supplied to these cylinders. In the preferred form of the invention the grinding wheel 10 and the beam 14 are moved at a relatively slow rate and the table 62 is moved at a relatively rapid rate so that the table 62 is moved back and forth several times during the time it takes the grinding wheel 10 to move from the rear corner of the billet 61 to the front corner of the billet 61.

Once the switches 183, 184, 192, 193, 181 and 182 have been set to the positions described above, the grinding wheel 10 will completely traverse the surface of a billet one or more times without any action on the part of an operator. When the surface of a billet has been ground to the desired extent, the automatic reciprocation of the table 62 and the beam 14 is discontinued, and the billet is unclamped, turned and reclamped so that a new surface of the billet may be ground by a similar operation.

Although I have illustrated and described the load controlling apparatus of my invention in connection with a grinding wheel that is mounted on a pivotally mounted beam, it will be apparent that such controlling apparatus may also be used to control the load on a grinding wheel mounted in other ways. Also, it will be apparent to those skilled in the art that the stops and limit switches for controlling the reciprocation of the beam 14 and the table 62 and for controlling the lifting of the grinding wheel 10 may be differently arranged.

Having thus described my invention with particular reference to the preferred form thereof, it will be obvious to those skilled in the art to which the invention pertains, after understanding my invention, that various changes and other modifications may be made therein without departing from the spirit and scope of my invention, as defined by the claims appended hereto.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. Apparatus for surface grinding billets comprising:

a pivotally mounted beam, means for mounting an abrasive grinding wheel on said beam, grinding wheel driving means, means for reciprocating said beam with respect to a billet and in a direction transverse to the axis of said wheel, means for rotating said beam about its pivot and means connected to said rotating means for actuating said rotating means in accordance with the load on said driving means comprising control means connected to said driving means and operable by the energy supplied thereto.

2. Apparatus for surface grinding billets comprising: a pivotally mounted beam, means for mounting an abrasive grinding wheel on said beam, grinding wheel driving means, means for reciprocating said beam in a direction transverse to its pivot, adjustable means for rotating said beam about its pivot point and means for actuating said adjustable means connected thereto and comprising control means connected to said means for driving said wheel and operable by the energy supplied thereto.

3. Apparatus for surface grinding billets comprising: a pivotally mounted beam, an abrasive grinding wheel mounted on said beam at a position spaced from the pivot point of said beam, an electric motor mounted on said beam and drivingly connected with said wheel, a counter-weight movably mounted on said beam on the opposite side of said pivot point from said wheel and means for varying the load on said wheel comprising electrically controlled means connected to said counter-weight for adjusting the position thereof, said electrically controlled means also being connected to the input circuit of said motor and responsive to the flow of current therein, whereby said counter-weight moves away from said pivot point with an increase in current and moves toward said pivot point with a decrease in current.

4. Apparatus for surface grinding billets comprising: a pivotally mounted beam, an abrasive grinding wheel mounted on said beam at a position spaced from the pivot point of said beam, an electric motor mounted on said beam on the same side of said pivot point as said wheel and drivingly connected with said wheel, a counter-weight movably mounted on said beam on the opposite side of said pivot point from said wheel and means for varying the load on said wheel comprising fluid actuated cylinder and piston means mounted on said beam and connected to said counter-weight, electrically actuated control means connected to said cylinder and piston means for controlling the supply of fluid thereto and for thereby causing said piston to move with respect to said cylinder in either of two directions and electrical switching means connected to said control means for causing operation of said control means, said switching means being connected to the input circuit of said motor and being responsive to current flow therein.

5. Apparatus for surface grinding billets comprising: a pivotally mounted beam, an abrasive grinding wheel mounted on said beam at a position spaced from the pivot point of said beam, an electric motor mounted on said beam on the same side of said pivot point as said wheel and drivingly connected with said wheel, a counter-weight movably mounted on said beam on the opposite side of said pivot point from said wheel and means for varying the load on said wheel comprising fluid actuated cylinder and piston means mounted on said beam and connected to said counter-weight, control means connected to said cylinder and piston means for controlling the supply of fluid thereto for alternatively moving the piston with respect to the cylinder in either of two directions and electrical connections between said motor and said control means for causing operation of said control means in response to the electrical current drawn by said motor, whereby said control means in cooperation with said cylinder and piston means causes said counter-weight to move away from said pivot point with an increase in current drawn and causes said counter-weight to move toward said pivot point with a decrease in current drawn.

6. Apparatus for grinding billets comprising a pivotally

mounted beam, means for moving said beam in a direction transverse to its pivot, means for mounting a grinding wheel on said beam, an electric motor for driving said wheel, and means for controlling the position of said mounting means with respect to a billet comprising a movable weight mounted on said beam, moving means connected to said weight for moving the weight along the beam, electrically operable control means connected to said moving means for controlling the operation thereof, and means for operating said control means comprising relay means connected to the input circuit of said motor and to said control means, said relay means being operable by the current in said input circuit of said motor.

7. Apparatus for grinding billets comprising means for movably mounting a grinding wheel, an electric motor for driving said wheel, and means for controlling the position of said mounting means with respect to a billet comprising fluid actuated cylinder and piston means connected to said mounting means, an electrically operable valve connected to said cylinder and piston means for controlling the supply of fluid thereto, a transformer coupled to the input circuit of said motor, a rectifier connected to said transformer, and means for operating said valve comprising relay means connected to said rectifier, and to said valve, said relay means being operable by the output of said rectifier.

8. Apparatus for grinding billets comprising means for movably mounting a grinding wheel, an electric motor for driving said wheel, and means for controlling the position of said mounting means with respect to a billet comprising fluid actuated cylinder and piston means connected to said mounting means, an electrically operable valve connected to said cylinder and piston means for controlling the supply of fluid thereto and having a pair of energizing coils, means for supplying energy to said coils, a transformer coupled to the input circuit of said motor, a rectifier connected to said transformer, and three-position relay means connected to said rectifier, to said coils and to said means for supplying energy to said coils, said relay means being controllable in position by the output of said rectifier and in a first position thereof connecting one of said energizing coils to said means for supplying energy thereto, in a second position thereof connecting the other of said energizing coils to said means for supplying energy thereto, and in a third position thereof disconnecting said coils from said means for supplying energy thereto.

9. Apparatus for surface grinding billets comprising: a movable table for supporting a billet and means for reciprocating said table connected thereto; a pivotally and movably mounted beam, said beam being mounted with its pivot axis substantially parallel to the path of travel of said table, and an abrasive wheel mounted on said beam; means for driving said wheel; a counter-weight movably mounted on said beam, means connected to said driving means and to said weight and responsive to the power consumption of said driving means for adjusting the position of said weight in accordance with the load on said wheel, and means connected to said beam for reciprocating said beam in a direction transverse to the direction of movement of said table.

10. Apparatus for surface grinding billets comprising: a movable table for supporting a billet, means for reciprocating said table connected thereto, and control means connected to and actuated by said reciprocating means in predetermined positions thereof for controlling the movements thereof; a pivotally and movably mounted beam, said beam being mounted with its pivot axis substantially parallel to the path of travel of said table, and an abrasive wheel mounted on said beam on one side of said pivot axis; means for driving said wheel; a counter-weight movably mounted on said beam, means connected to said weight for adjusting the position thereof and control means connected to said last-mentioned means for actuation thereof in accordance with the load on said wheel,

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said last-mentioned control means also being connected to said driving means and responsive to the power consumption thereof; means connected to said beam for reciprocating said beam in a direction transverse to the direction of movement of said table, and control means connected to and actuable by said last-mentioned reciprocating means in predetermined positions thereof for controlling the movements thereof.

11. Apparatus for surface grinding billets comprising: a movable table for supporting a billet, means for reciprocating said table connected thereto, and control means connected to and actuated by said reciprocating means in predetermined positions thereof for controlling the movements thereof; a pivotally and movably mounted beam, said beam being mounted with its pivot axis substantially parallel to the path of travel of said table, an abrasive wheel mounted on said beam on one side of said pivot axis and an electric motor drivingly connected with said wheel and mounted on said beam; a counter-weight movably mounted on said beam, means connected to said weight for adjusting the position thereof and control means connected to said last-mentioned means for actuation thereof in accordance with the load on said wheel, said last-mentioned control means also being electrically connected to said electric motor and responsive to the load current thereof; and means connected to said beam for reciprocating said beam in a direction transverse to the direction of movement of said table, and control means connected to and actuable by said last-mentioned reciprocating means in predetermined positions thereof for controlling the movements thereof.

12. Apparatus for surface grinding billets comprising: a movable table for supporting a billet and means for moving said table in a predetermined direction comprising fluid actuated cylinder and piston means connected to said table, control means connected to said cylinder and piston means for controlling the supply of fluid thereto and for causing movement of said table in said direction and adjustable stop means engageable with said control means in different positions of said table for operating said control means, one of said two last-mentioned means being connected to and movable by said table; a pivotally and movably mounted beam, said beam being mounted with its pivot axis substantially parallel to the direction of travel of said table, an abrasive wheel mounted on said beam on one side of the pivot point thereof, and an electric motor drivingly connected with said wheel and mounted on said beam on the same side of said pivot point as said wheel; a counter-weight movably mounted on said beam on the side of said pivot point opposite from said wheel, fluid actuated cylinder and piston means connected to said weight for moving said weight and means for adjusting the position of said weight in accordance with the load on said wheel comprising control means connected with said last-mentioned cylinder and piston means for controlling the supply of fluid thereto, said last-mentioned control means also being electrically connected to said electric motor and responsive to the load current thereof to change the supply of fluid to said last-mentioned cylinder and piston means, and means for reciprocating said beam in a direction transverse to the direction of movement of said table comprising fluid actuated cylinder and piston means connected to said beam, control means connected to said last-mentioned cylinder and piston means for controlling the supply of fluid thereto and adjustable stop means engageable with said last-mentioned control means in different predetermined positions of said beam for operating said last-mentioned control means, one of said two last-mentioned means being connected to and movable by said beam.

13. Apparatus for surface grinding billets comprising: a stationary frame, a table movably mounted on said frame for supporting and reciprocating a billet, and means for moving said table in either of two opposite directions comprising fluid actuated cylinder and piston

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means connected between said table and said frame, control means mounted on said table for controlling the supply of fluid to said cylinder and piston means and adjustable stop means mounted on said frame and engageable with said control means in different predetermined positions of said table for operating said control means; a further stationary frame, a beam pivotally and movably mounted on said further frame, said beam being movable in a direction transverse to the direction of movement of said table, an abrasive wheel mounted on one end of said beam and an electric motor drivingly connected with said wheel and mounted on said beam on the same side of the pivot point of said beam as said wheel; a counter-weight movably mounted on said beam on the side of said pivot point opposite from said wheel, fluid actuated cylinder and piston means mounted on said beam and connected to said weight for adjusting the position thereof and control means connected to said last-mentioned cylinder and piston means for controlling the supply of fluid thereto, said last-mentioned control means also being electrically connected to said electric motor and responsive to the load current thereof to change the supply of fluid to said last-mentioned cylinder and piston means; and means for reciprocating said beam in a direction transverse to the direction of movement of said table comprising fluid actuated cylinder and piston means connected between said further frame and said beam, control means mounted on said further frame for controlling the supply of fluid to said last-mentioned cylinder and piston means and adjustable stop means movable by said last-mentioned cylinder and piston means and engageable with said last-mentioned control means in different predetermined positions of said beam for operating said last-mentioned control means.

14. Apparatus for surface grinding billets comprising: a stationary frame, a table movably mounted on said frame for supporting and reciprocating a billet, and means for moving said table in either of two opposite directions comprising fluid actuated cylinder and piston means connected between said table and said frame and operable in either of two directions, control means mounted on said table for controlling the supply of fluid to said cylinder and piston means and adjustable stop means mounted on said frame and engageable with said control means in different predetermined positions of said table for operating said control means; a further stationary frame, a pair of shafts mounted in spaced and parallel relation on said further frame and secured thereto, said shafts being mounted with their longitudinal axes perpendicular to the direction of movement of said table, a pair of bearings, each slidably mounted on one of said shafts, a pivot shaft mounted at its ends in said bearings, a beam mounted on said pivot shaft at a point intermediate the ends of said beam, an abrasive wheel mounted on one end of said beam with its axis of rotation extending substantially parallel to the direction of movement of said table and an electric motor drivingly connected with said wheel and mounted on said beam on the same side of said pivot shaft as said wheel; a counter-weight movably mounted on said beam on the side of said pivot shaft opposite from said wheel, fluid actuated cylinder and piston means mounted on said beam and connected to said weight for adjusting the position thereof and control means connected to said last-mentioned cylinder and piston means for controlling the supply of fluid thereto, said last-mentioned control means also being electrically connected to said electric motor and responsive to the load current thereof to change the supply of fluid to said last-mentioned cylinder and piston means whereby the position of said counter-weight is varied in accordance with said load current; and means for reciprocating said beam in a direction transverse to the direction of movement of said table comprising fluid actuated cylinder and piston means connected between said further frame and said pivot shaft, control means mounted on said further

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frame for controlling the supply of fluid to said last-mentioned cylinder and piston means and adjustable stop means movable by said last-mentioned cylinder and piston means and engageable with said last-mentioned control means in different predetermined positions of said beam for operating said last-mentioned control means.

15. Apparatus for surface grinding billets comprising: a stationary frame, a table movably mounted on said frame for supporting and reciprocating a billet, and means for moving said table in either of two opposite directions comprising fluid actuated cylinder and piston means connected between said table and said frame and operable in either of two directions, control means mounted on said table for controlling the supply of fluid to said cylinder and piston means and adjustable stop means mounted on said frame and engageable with said control means in different predetermined positions of said table for operating said control means; means mounted on said table for clamping a billet thereon comprising a movable billet engaging member and fluid actuated cylinder and piston means connected to said engaging member for causing movement thereof; means mounted on said table for rotating a billet about its longitudinal axis comprising a turning finger engageable with said billet and fluid actuated cylinder and piston means connected to said finger for causing movement thereof; a further stationary frame, a pair of shafts mounted in spaced and parallel relation on said further frame and secured thereto, said shafts being mounted with their longitudinal axes perpendicular to the direction of movement of said table, a pair of bearings, each slidably mounted on one of said shafts, a pivot shaft mounted at its ends in said bearings, a beam mounted on said pivot shaft at a point intermediate the ends of said beam, an abrasive wheel mounted on one end of said beam with its axis of rotation extending substantially parallel to the direction of movement of said table and an electric motor drivingly connected with said wheel and mounted on said beam on the same side of said pivot shaft as said wheel; a counter-weight movably mounted on said beam on the side of said pivot shaft opposite from said wheel, fluid actuated cylinder and piston means mounted on said beam and connected to said weight for adjusting the position thereof and control means connected to said last-mentioned cylinder and piston means for controlling the supply of fluid thereto, said last-mentioned control means also being electrically connected to said electric motor and responsive to the load current thereof to change the supply of fluid to said last-mentioned cylinder and piston means whereby the position of said counter-weight is varied in accordance with said load current; and means for reciprocating said beam in a direction transverse to the direction of movement of said table comprising fluid actuated cylinder and piston means connected between said further frame and said pivot shaft, control means mounted on said further frame for controlling the supply of fluid to said last-mentioned cylinder and piston means and adjustable stop means movable by said last-mentioned cylinder and piston means and engageable with said last-mentioned control means in different predetermined positions of said beam for operating said last-mentioned control means.

16. Grinding apparatus comprising a table for holding a piece to be ground, means for reciprocating said table connected thereto, means for mounting a grinding wheel adjacent said piece, means actuated by said reciprocating means for reversing the movement of said reciprocating means at the end of each reciprocatory stroke thereof and timing means connected to said reciprocating means, said timing means operating at predetermined times independently of the movement of said reciprocating means and being adapted to reverse the movement of said reciprocating means at said times.

17. Grinding apparatus comprising a table for holding a piece to be ground, means for reciprocating said table, means for mounting a grinding wheel adjacent said table,

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means for reciprocating said mounting means and means for clamping said piece on said table comprising a first clamp member slidably mounted on said table, a second clamp member pivotally mounted on said first clamp member and means for forcing said second clamp member against said piece.

18. Grinding apparatus comprising a table for holding a piece to be ground, means for reciprocating said table, means for mounting a grinding wheel adjacent said table, means for reciprocating said mounting means and means for clamping said piece on said table comprising a first clamp member mounted on said table and slidable along a predetermined path, a second clamp member pivotally mounted on said first clamp member and means connected to said second clamp member for exerting a force thereon directed along a path at an angle to said first-mentioned path.

19. Grinding apparatus comprising a table for holding a piece to be ground, means for reciprocating said table, means for mounting a grinding wheel adjacent said table, means for reciprocating said mounting means and means for clamping said piece on said table comprising a first clamp member mounted on said table and slidable along a predetermined path, a second clamp member pivotally mounted on said first clamp member, means connected to said first clamp member for urging said first clamp member away from said piece and means connected to said second clamp member for urging both said clamp members toward said piece.

20. Clamping means comprising a support, a first clamp member slidably mounted on said support, a second clamp member pivotally mounted on said first clamp member and means connected to said second clamp member and acting between said support and said second clamp member for forcing both said members against a piece to be clamped.

21. Billet grinding apparatus comprising a table for carrying a billet, means for reciprocating said table connected thereto, means for mounting a grinding wheel adjacent said billet, means for reciprocating said mounting means crosswise of said table connected to said mounting means and means for clamping said billet on said table comprising a first clamp member slidable along a path extending toward and away from the end of said billet and engageable with the end of said billet, means acting between said clamp member and said table and urging said clamp member away from said end of said billet, a second clamp member pivotally mounted at one end on said first clamp member, said second clamp member having a billet engaging portion at the opposite end thereof and operating means mounted on said table and connected to said second clamp member, said operating means being adapted to apply a force to said second clamp member directed along a path which intersects the path of said first clamp member at an acute angle.

22. Billet grinding apparatus comprising a table for carrying a billet, means for reciprocating said table connected thereto, means for mounting a grinding wheel adjacent said billet, means for reciprocating said mounting means crosswise of said table connected to said mounting means and means for clamping said billet on said table comprising a first clamp member slidable along a path extending toward and away from the end of said billet and engageable with the end of said billet, spring means acting between said clamp member and said table and urging said clamp member away from said end of said billet, a second clamp member pivotally mounted at one end on said first clamp member, said second clamp member having a billet engaging roller at the opposite end thereof, and cylinder and piston means mounted on said table and having a piston rod connected to said second clamp member intermediate the ends thereof, said cylinder and piston means being mounted with said piston rod movable along a path which intersects the path of said first clamp member at an acute angle.

23. Billet grinding apparatus comprising a table for holding a billet to be ground, means for reciprocating said table connected thereto, means for mounting a grinding wheel adjacent said billet, and means for controlling the movement of said reciprocating means comprising means actuated by said reciprocating means at predetermined positions thereof for reversing the direction of movement of said reciprocating means and timing means connected to said reciprocating means, said timing means operating at predetermined times independently of the movement of said reciprocating means and being adapted to reverse the direction of movement of said reciprocating means at said times.

24. Billet grinding apparatus comprising a table for holding a billet to be ground, means for reciprocating said table connected thereto and comprising fluid actuated cylinder and piston means, means for mounting a grinding wheel adjacent said billet, means for controlling the supply of fluid to said cylinder and piston means, means connected to said controlling means and actuated by said reciprocating means for reversing the direction of movement of said reciprocating means at predetermined positions of said table and timing means connected to said controlling means for reversing the direction of movement of said reciprocating means, said timing means

comprising means operating at predetermined times independently of the movement of said reciprocating means for actuating said controlling means at said times.

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