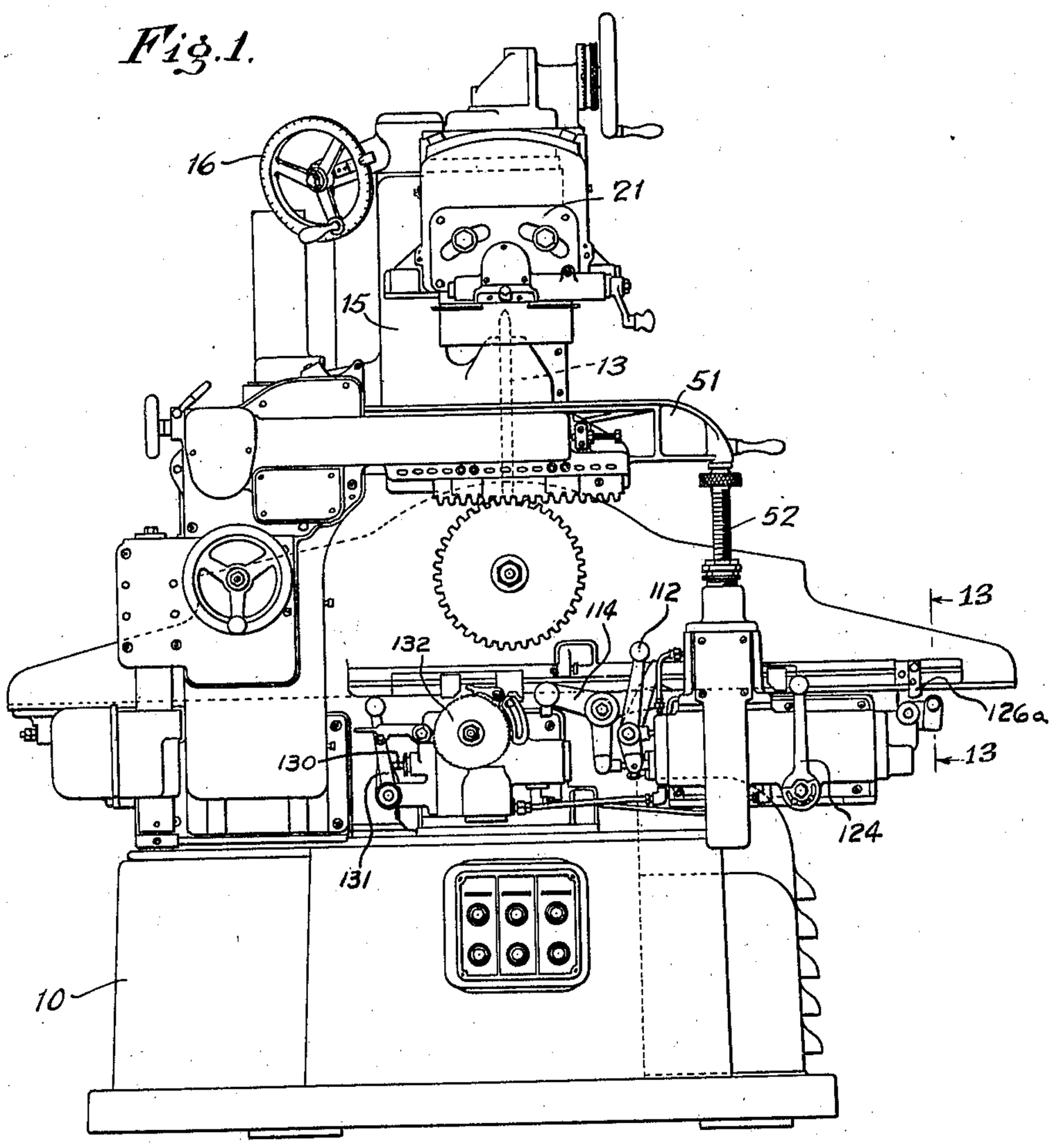
Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 1

Fig. 1.



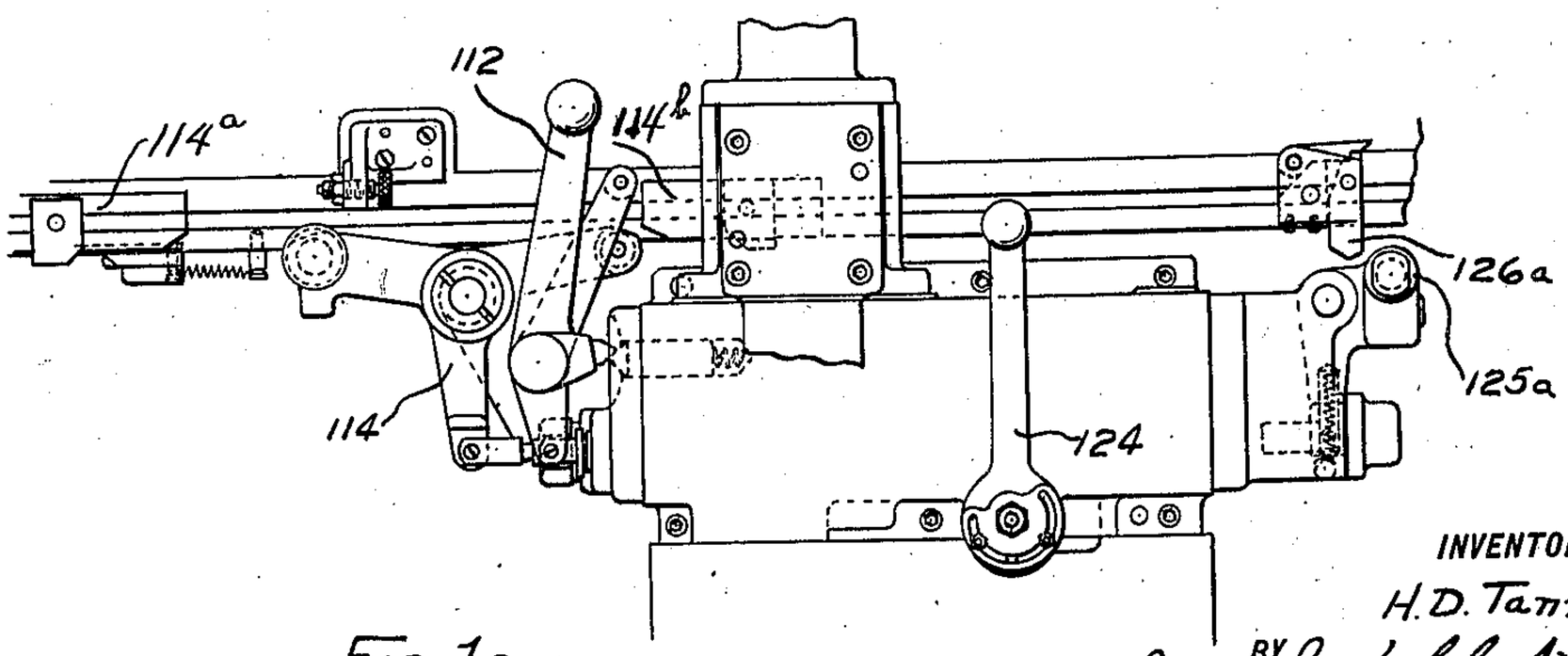


Fig. 1a

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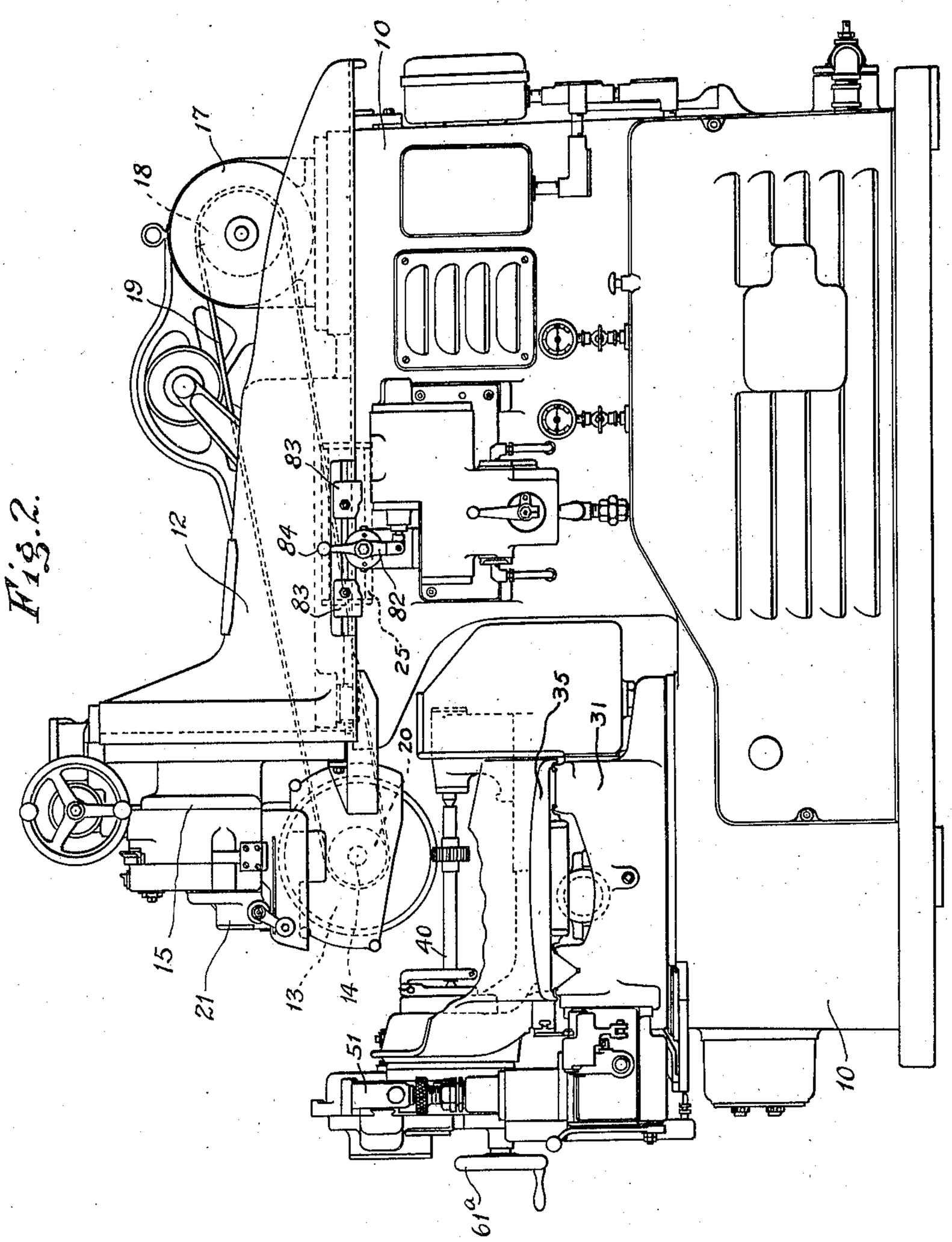
Filed Sept. 9, 1933 9 Sheets-Sheet 2

Fig. 2.



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Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 3

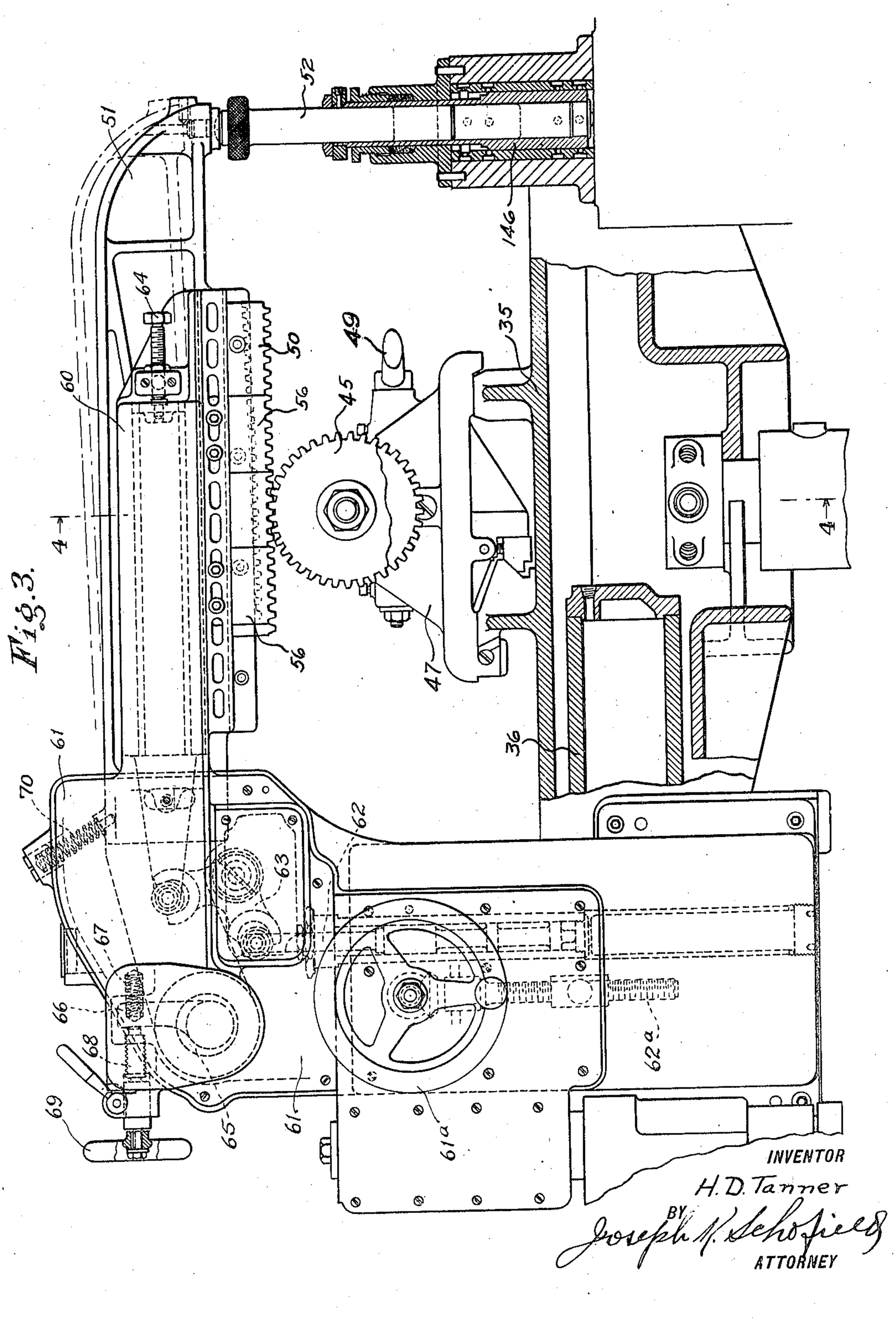

Fig. 3.

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Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 4

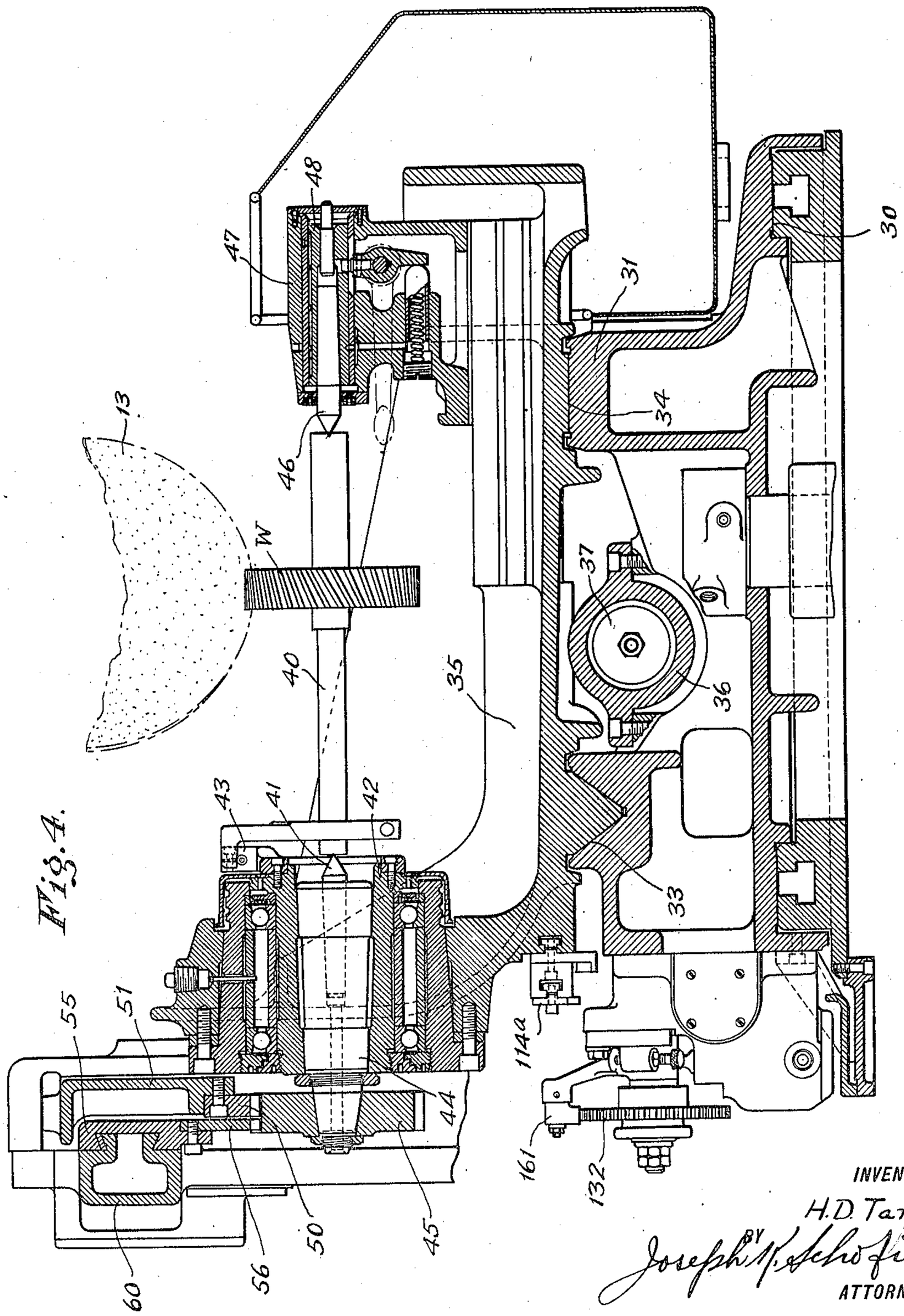

Fig. 4.

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Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 5

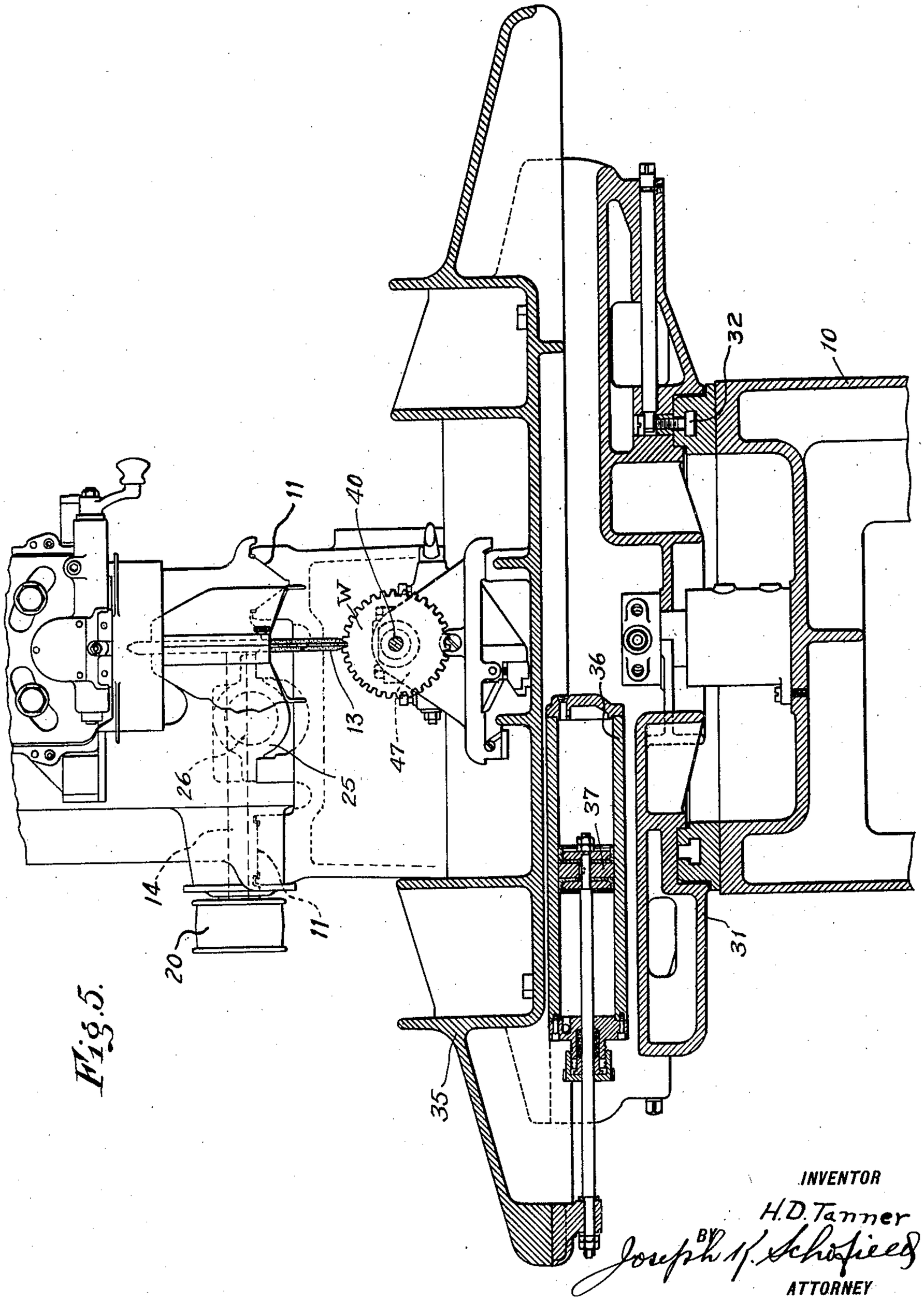

Fig. 5.

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Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 6

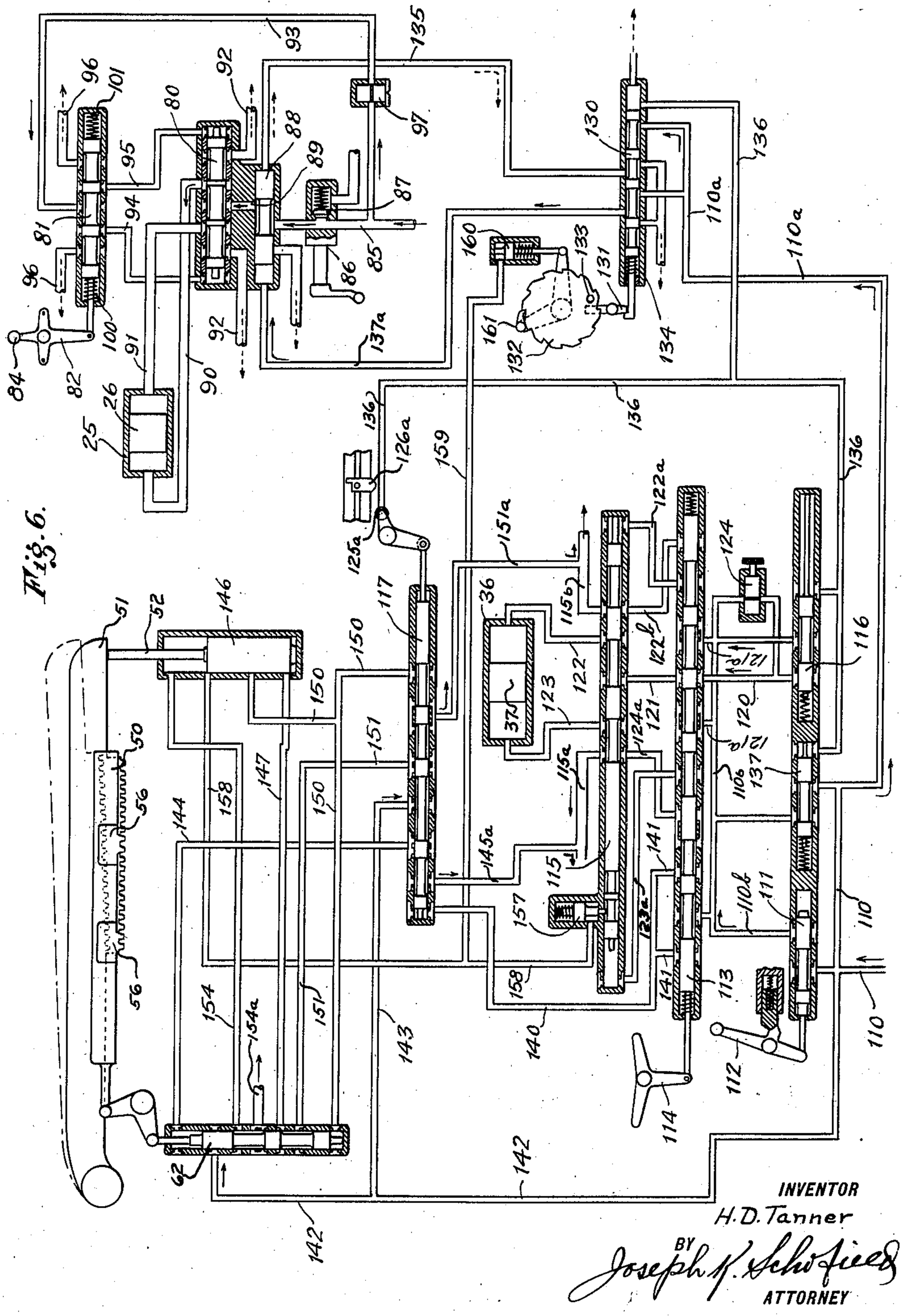

Fig. 6.

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Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 7

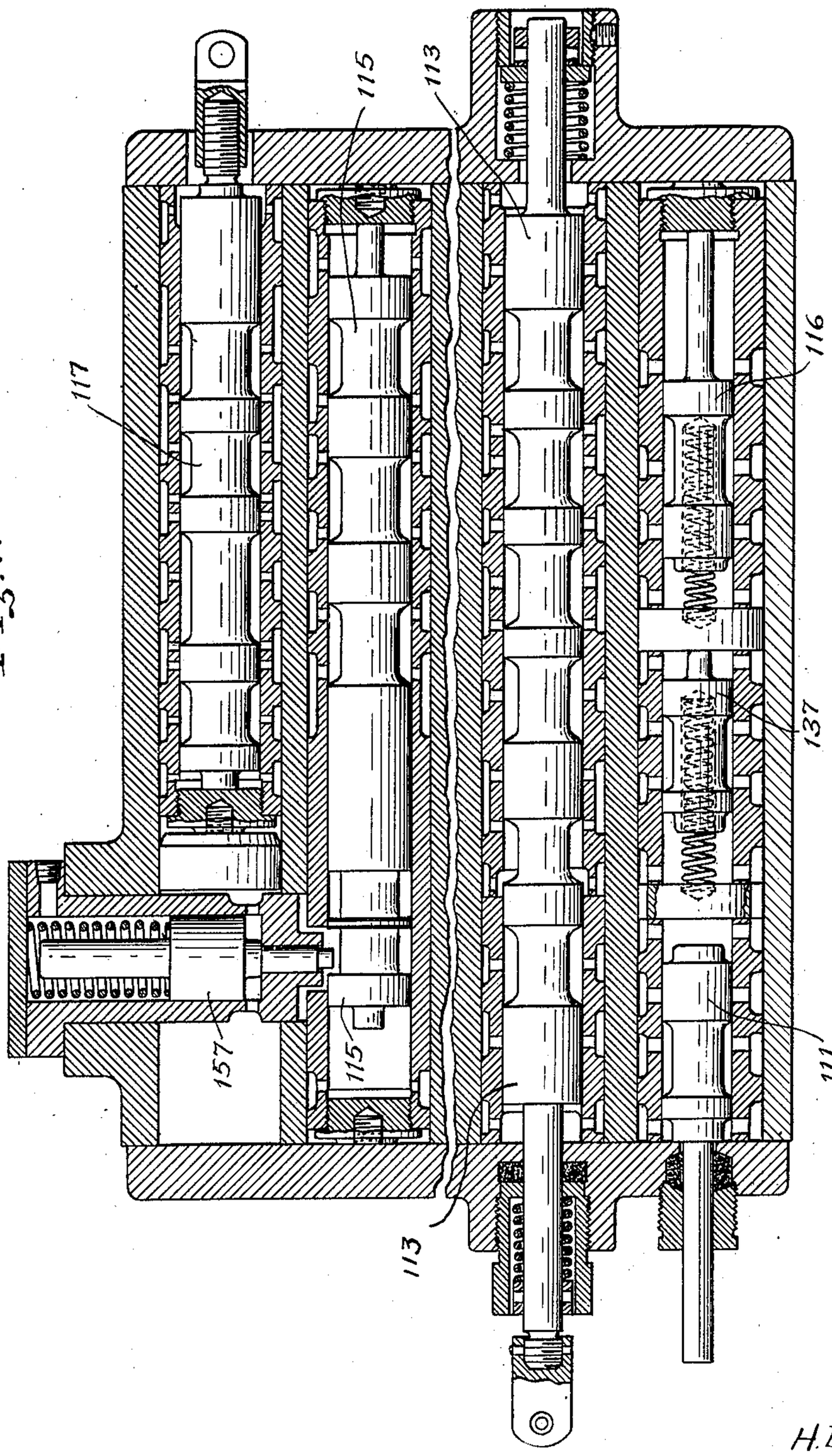

Fig. 7.

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Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 8

Fig. 8.

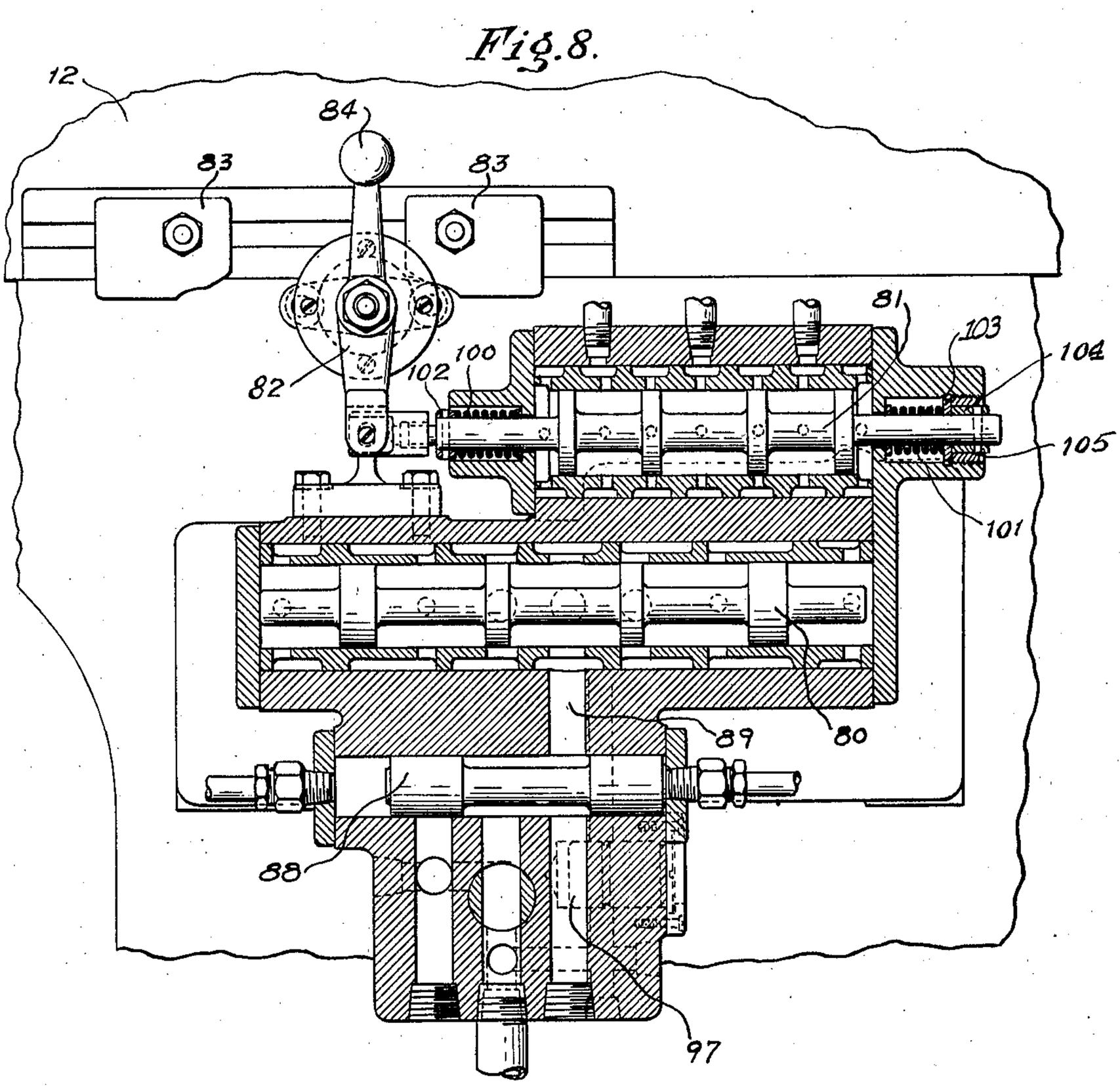
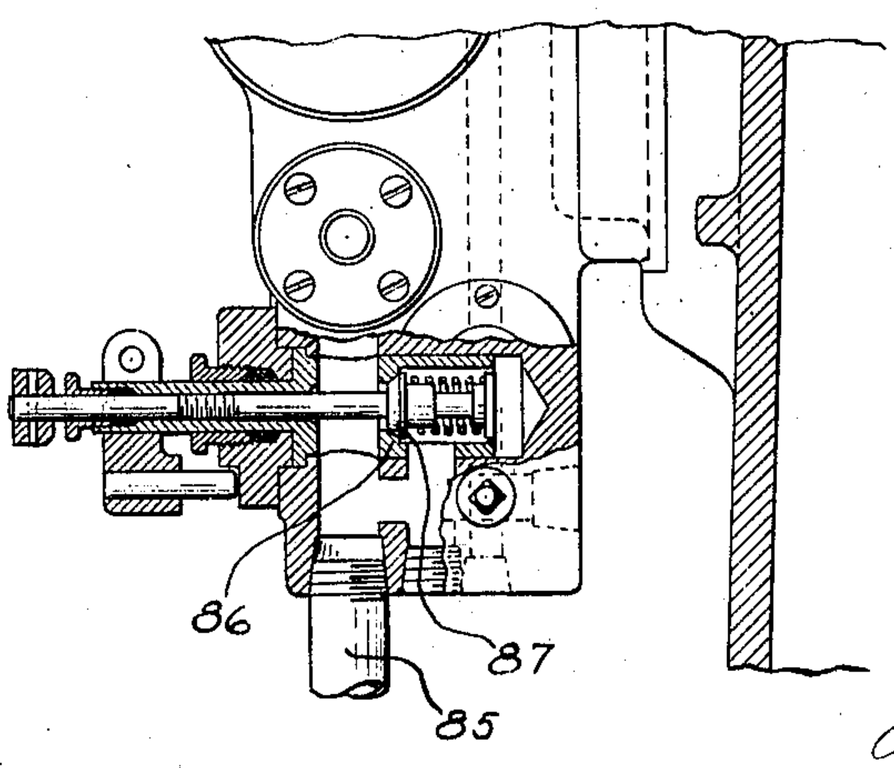


Fig. 9.



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Nov. 26, 1935. H. D. TANNER 2,022,061

GEAR GRINDER

Filed Sept. 9, 1933 9 Sheets-Sheet 9

Fig. 11.

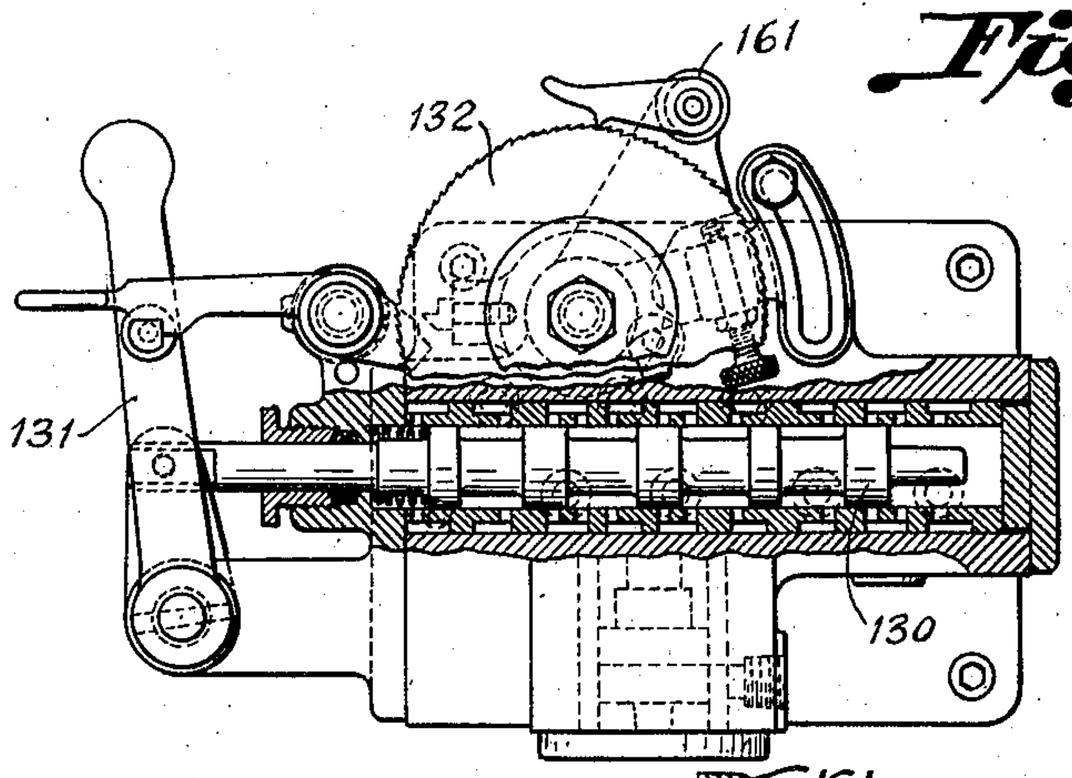

Fig. 10.

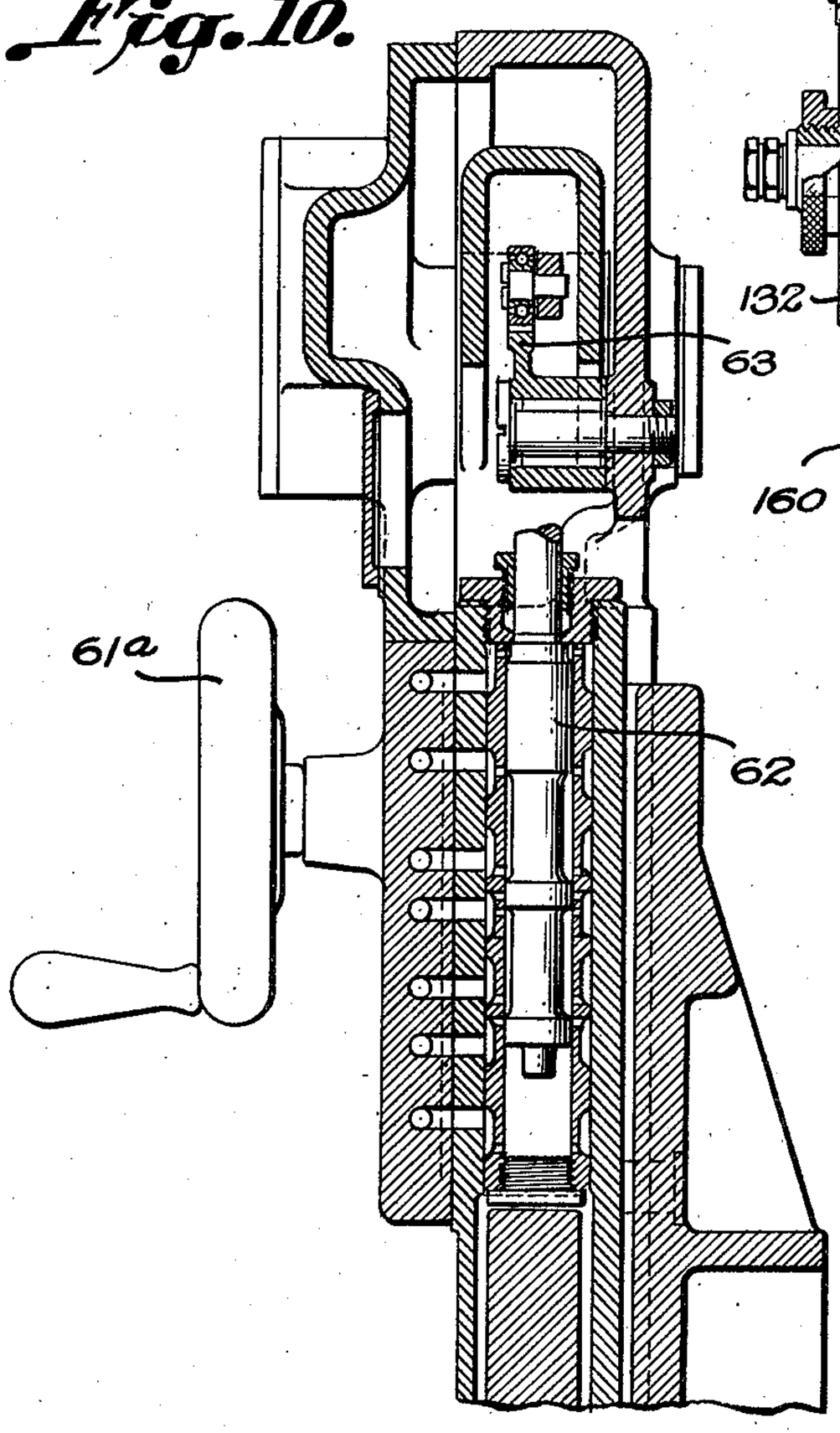

Fig. 12.

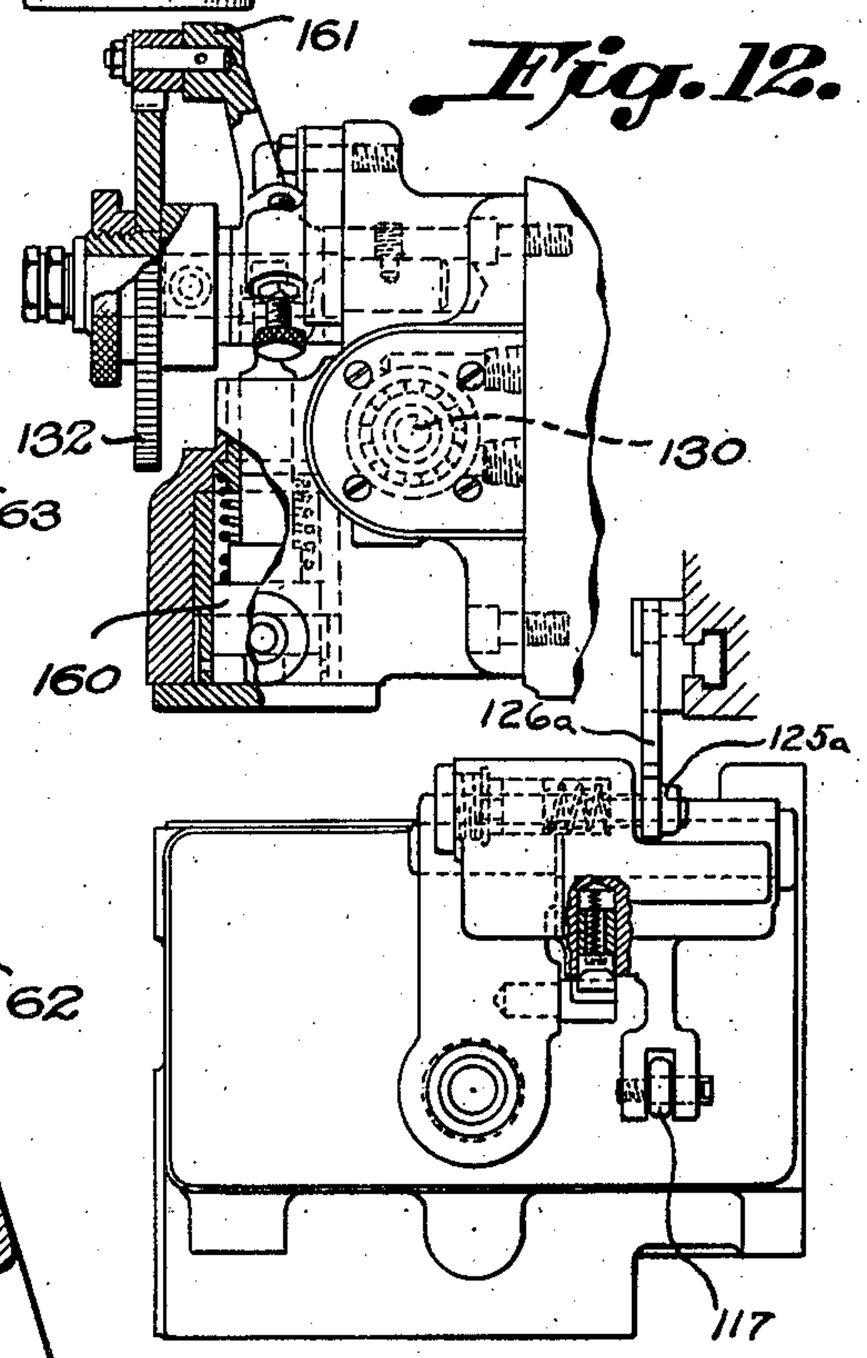

Fig. 13.

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Patented Nov. 26, 1935 2,022,061

UNITED STATES PATENT OFFICE

2,022,061

GEAR GRINDER

Hubert D. Tanner, West Hartford, Conn., assignor to Pratt & Whitney Company, Hartford, Conn., a corporation of New Jersey

Application September 9, 1933, Serial No. 688,714

12 Claims. (Cl. 51—123)

This invention relates to gear tooth grinders and particularly to a grinder for forming involute tooth curves of spur and helical gears by generative movements between an abrasive wheel and the gear blank being ground.

A primary object of the invention is to provide an improved hydraulically operated gear tooth grinder of the type in which a single grinding wheel beveled on opposite sides to form opposed frustums of cones is reciprocated relative to and within the tooth spaces of a gear being ground so that its work engaging surfaces may pass successively through spaces between adjacent teeth, the support for the gear blank and wheel being adjustable to adapt the machine for gears of different diameters and for teeth of any number and any helix angle, the gear being ground being also rotatable upon its axis and movable laterally for effecting the generating movements thereof relative to the wheel.

Another object of the invention is to provide hydraulic means to effect indexing of the gear and also to effect the rolling movements of the gear blank laterally past the grinding wheel, these hydraulic means cooperating with an intermeshing master rack and master gear and indexing rack slide to effect the rolling movement of the gear upon a pitch circle of any predetermined diameter and the indexing movement.

Another feature of importance of the invention is that the cycle of operation of the machine is controlled by and the movable parts are operated by hydraulic means operating in a predetermined cycle, the wheel reciprocating and the gear blank actuating and indexing means having individual fluid actuated members each controlled by its distributing valves, and hydraulically controlled inter-locking means also being provided in the hydraulic systems to prevent improper functioning or operation of the elements of the machine during the cycle of operation of the machine.

And finally it is a primary object of the invention to provide improved hydraulic systems for the machine, one operating the ram on which the wheel is carried and the other system having separate circulating means for controlling movements of the gear supporting table and for operating the indexing mechanism so that the movements of the gear during the period of grinding will be unaffected by fluctuations in pressure within the hydraulic system due to the rapid reciprocations of the heavy wheel carrying ram.

With the above and other objects in view my invention includes the features of construction and operation set forth in the following specification and illustrated in the accompanying drawings.

In the accompanying drawings annexed hereto and forming a part of this specification, I have shown my invention embodied in a machine for grinding involute teeth of spur and helical gears, but it will be understood that the invention can be otherwise embodied and that the drawings are not to be construed as defining or limiting the scope of the invention, the claims appended to this specification being relied upon for that purpose.

Figure 1 is a front elevation of a complete machine forming the present invention, the wheel head being shown in position for a gear of maximum diameter.

Fig. 1*a* is a fragmentary portion of Fig. 1 upon an enlarged scale showing some of the table controlling mechanism.

Fig. 2 is a side elevation of the complete machine taken from the right hand side of Fig. 1, the gear being ground being shown of relatively small diameter.

Fig. 3 is a fragmentary front elevation partly in section showing the work supporting and indexing means, and actuating mechanism therefor.

Fig. 4 is a sectional view in elevation of the work supporting and actuating mechanism, the section being taken upon the plane of line 4—4 of Fig. 3 but with the work support adjusted angularly to an oblique position for grinding a helical gear.

Fig. 5 is a sectional view of the parts shown in Fig. 4 taken upon a vertical plane at right angles to Fig. 4.

Fig. 6 is a diagrammatic view of the hydraulic system for actuating the movable parts of the machine for effecting their operation in accordance with a definite cycle.

Fig. 7 is a sectional view of the main hydraulic valves controlling admission of fluid to the work actuating mechanism and to the work indexing mechanism, the view being developed to show the valves in a single plane to more clearly show their construction.

Fig. 8 is a sectional view of the valve mechanism controlling admission of fluid to the wheel reciprocating motor, the valves being shown in a single plane to more clearly show their construction.

Fig. 9 is a fragmentary view of the valves shown in Fig. 8 disposed in their correct relative

positions, the view being taken from the right hand side of Fig. 8.

Fig. 10 is a sectional view of the hydraulic mechanism for effecting movements of the indexing rack and controlling the movements of the master rack into and out of operative position.

Fig. 11 is a front view in elevation of the automatic knockoff and manual control valve for the complete machine.

Fig. 12 is a side view of the valve and associated mechanism shown in Fig. 11, and

Fig. 13 is a detail end view of one of the valves taken on line 13—13 of Fig. 1.

In the above mentioned drawings I have shown but one embodiment of the invention which is now deemed preferable and which is designed primarily for finishing automobile transmission gears by grinding their curved tooth surfaces, but it is to be understood that changes and modifications may be made within the scope of the appended claims without departing from the spirit of the invention.

Briefly and in its broadest aspect, my invention preferably includes the following principal parts: First, a base; second, a ram reciprocable thereon horizontally in a fixed direction and having a rotatable abrasive wheel adjustably mounted at its forward end; third, a work supporting carriage on the base angularly adjustable about a vertical axis normal to the path of movement of the wheel and ram; fourth, a work supporting slidable table on said carriage; fifth, means for supporting a work blank on said slidable table for free rotation; sixth, hydraulic means to reciprocate the table on its carriage in any angular adjustment thereof; seventh, a master rack supported upon said carriage engaging, when in operative positions, a master gear on the work carrying spindle; eighth, hydraulic means to disengage and re-engage said master rack relative to said master gear; ninth, hydraulically operating indexing means periodically engaging and rotating said master gear and gear being ground when the master rack is disengaged from its gear and the wheel is disengaged from the gear blank being ground; and tenth, fluid distributing means to actuate the operative members referred to above varying predetermined amounts and in accordance with a predetermined definite cycle of operation, there being manually operated means to regulate the hydraulic systems and means to stop the machine at the end of its operation upon a gear.

In the illustrated form of the invention the machine is adapted for either spur or helical gears in either case depending upon the angular adjustment of the gear supporting table and carriage. However, the master gear is of spur type and meshes with a spur rack whether the gear being ground is spur or helical. In the drawings, with the exception of Fig. 4, the work supporting table is shown in position for grinding spur gears. Fig. 4, however, shows an oblique position of the work supporting means relative to the wheel suitable for grinding a helical gear.

In the operation of the present machine the abrasive wheel mounted on and adjustably carried by its ram is reciprocated rapidly past a gear blank during a slow rolling movement of the gear blank, the angle between the axis of the gear and the direction of movement of the ram during this rolling movement being equal to the desired helix angle of the gear being ground. The operation of the ram and the rolling movement of the gear are effected by means generally similar to those described and shown in the patent to Garrison 1,823,734 granted September 15, 1931. The present application discloses and claims improvements upon what is shown and described in said patent. When the gear has been rolled past the wheel completely grinding adjacent sides of adjacent teeth of the gear, the gear is indexed and the gear rolled back to its initial position. Indexing may preferably take place at opposite ends of the rolling movements of the gear. Indexing, however, may be effected at one end only of the reciprocation of the gear supporting carriage. The method of indexing is generally similar to that described in the above mentioned patent to Garrison and will be presently described in connection with the description of the hydraulic system by means of which it is controlled and operated.

Referring more in particular to the figures of the drawings, I provide a base 10 with horizontal ways 11 supporting a ram 12 for reciprocatory movement horizontally in a fixed direction. Rotatably supported at one end of the ram 12 is an abrasive wheel 13 mounted upon a horizontal transverse shaft 14 within a head 15. The head 15 is preferably adjustable vertically to adjust the wheel for gears of different diameters. This is accomplished by means of hand wheel 16 and connections within guideways at the forward end of the ram 12. A motor 17 for rotating the wheel 13 at high speed may be conveniently mounted directly on the ram 12 having a driving pulley 18 connected by a belt 19 to a pulley 20 on the wheel carrying shaft 14. As these members form no part of the present invention, no further description is thought to be necessary. Also mounted on the head 15 carrying the wheel 13 is a dressing attachment 21 for the work engaging surfaces of the wheel 13. As this attachment forms no part of the present invention further description will be unnecessary. The work engaging surfaces of the wheel 13 which are acted upon by the dressing attachment 21 are of frusto-conical form and disposed on opposite sides of the wheel periphery. These frustums by suitably adjusting the direction of movement of the tools of the dressing attachment 21 may be formed at any desired angle. These frusto-conical surfaces also are similar to those on the wheel described and shown in the above referred to Garrison patent for grinding spur gears and the angle between their elements corresponds to the angles on the sides of rack teeth adapted to mesh with the gear being ground.

To reciprocate the ram 12 a cylinder 25 is mounted in fixed position within the base 10 extending parallelly to the direction of movement of the ram 12. A piston 26 within this cylinder 25 has attached thereto a connecting rod which at its outer end is fastened to a depending bracket on the ram 12. By alternately admitting fluid to the opposite ends of cylinder 25 the ram 12 may be operated at any desired speed and length of stroke. The means to admit fluid to the ram cylinder 25 to effect this reciprocation will be described in connection with the hydraulic systems of the machine. This reciprocation of the ram 12 is continued during operation of the machine, that is, during the rolling of the gear W past the wheel 12 and during the indexing operations. At the completion of the grinding operation upon a gear the ram reciprocations are stopped, means for effecting this and for stopping operation of the gear support being described as part of their hydraulic system.

Mounted on a horizontal circular supporting way 30 on the circular front of the base 10 is an angularly adjustable support or carriage 31. The supporting carriage 31 may be adjusted rotatively about a central vertical axis by means of any suitable means not shown to position the carriage at any desired angle to the direction of ram movement. In Fig. 4 the carriage 31 is shown adjusted obliquely relative to the wheel 13 for grinding helical gears whereas in Figs. 1, 3, and 5 the position shown of the carriage 31 is such that the axis of the gear W being ground is at right angles to the direction of reciprocation of the ram 12 adapting the machine for grinding spur gears. The carriage 31 may be clamped in any adjusted angular position by bolts 32 engaging within a circular T slot in the base 10. The upper portion of this carriage or support 31 is provided with transverse horizontal ways, preferably a V way 33 and a flat way 34, on which may reciprocate a table 35 supporting the gear W being ground. To reciprocate the table 35 upon the ways 33 and 34 a cylinder 36 is mounted fixedly on the carriage 31 having a piston 37 therein connected by its connecting rod to a portion of the table 35. By means presently to be described in connection with the hydraulic mechanism fluid may be admitted under pressure alternately to opposite ends of this cylinder 36 to reciprocate the table 35 to move the gear W being ground laterally past the wheel 13 at predetermined speeds and for any desired length of stroke.

On the table 35 the gear W being ground is supported upon a shaft or arbor 40, the gears shown in the different figures having different diameters in different views. The shaft or arbor 40 supporting the gear W is mounted between centers carried by the table 35. This is best shown in Fig. 4. One of the centers 41 is mounted in a sleeve 42 carried upon ball bearings within a headstock portion preferably integrally formed on the table 35. On the sleeve 42 is a driving member 43 for attachment to a driving dog on the arbor 40 carrying the gear so that the gear being ground will be rotated with the sleeve 42. Preferably within the sleeve 42 and carrying the work supporting center 41 is a shaft 44 secured to the sleeve 42 for rotation therewith. Upon the extended forward end of this shaft 44 is secured a master gear 45 of the spur type but having the same number of teeth and the same pitch diameter as the gear W being ground.

Supporting the opposite end of the shaft or arbor 40 is a center 46 supported within a tailstock 47. As shown in Fig. 4 this tailstock 47 may be adjusted toward and from the headstock center 41 and may be clamped in adjusted position by means not shown. The tailstock center 46 preferably may be mounted within a spring pressed plunger 48 retractable by a hand lever 49 in the usual manner to insert the gear W being ground. By the above means the gear W being ground is mounted for rotary movement about its own axis and also for lateral movement with the table 35 in a direction normal to its axis. Furthermore, by adjustment of the carriage 31 this lateral movement of the gear W being ground may be at any predetermined angle to the direction of motion of the ram 12 carrying the abrasive wheel 13.

Meshing with the master gear 45 secured to and rotating with the gear W being ground is a master rack 50 normally but removably supported in fixed position on the lower surface of a horizontal arm 51. The arm 51 is pivotally mounted at one end upon an upwardly extended portion of the rotatable table carriage and at its free end rests upon the upper adjustable end of a vertically movable rod 52 also secured to the table 31. The means for hydraulically raising and lowering this rod 52 will presently be described. It will be seen from the drawings that with the arm 51 in its lower or horizontal position the teeth of the rack 50 engage the teeth of the master gear 45. Movement of the vertical rod 52 upward disengages the rack from the master gear 45 and permits rotation of the master gear 45 and the gear W being ground upon their common axis. The means to rotate or index the gear W and its shaft 44 when the rack 50 is disengaged from master gear 45 will now be described.

Disposed closely adjacent and parallel to the rack 45 is a horizontally disposed longitudinally movable member 55 carrying pawl or tooth members 56 in positions sufficiently spaced apart to engage the master gear 45 only when the table 35 is approaching opposite ends of its stroke. The hydraulic means to move the horizontal member 55 in a direction to effect rotary or indexing movement of the master gear 45, gear W and parts rotatable therewith will be described presently. Movement of the member 55 is made to take place only when the rack 50 engaging the master gear 45 has been elevated and disengaged therefrom. The engagement of one of the sets of teeth 56 and movement of member 55 a predetermined distance causes an indexing movement of the gear W being ground to be effected. As soon as this indexing movement of the member 55 is complete the arm 51 carrying the master rack 50 again moves down to engage the master gear 45 with the master rack 50, the master gear 45 and the gear W then being in an indexed position. Preferably indexing movement of the master gear 45 and gear being ground W occurs as above stated at each end of the stroke of the table 35, that is after each pass of the gear W past the wheel 13. The indexing member 55 is advanced to effect this indexing movement as the carriage 35 reaches the end of its stroke in each direction, the indexing member 55 remaining in its advanced position until the carriage 35 has reached an intermediate position on its next stroke so that its tooth members 56 will not contact with the master gear 45. The hydraulic means to move the member 55 at the proper time during the cycle of operation of the machine will presently be described. In the intermediate position of the carriage 35 the indexing member 55 may be moved back to its initial position at which time its tooth members 56 are disengaged from the master gear 45.

With the rack 50 engaging the master gear 45 the table 35 is slowly reciprocated upon its ways 33—34 on the angularly adjustable carriage 31 by hydraulic means presently to be more fully described. The effect of this movement is to roll the master gear 45 along the rack 50 and similarly roll the gear W below the path of the reciprocating wheel 13. The carriage 31 may be adjusted to any oblique position relative to the path of the wheel 13 so that the axis of the gear W being ground will be angularly disposed relative to the wheel 13 at an angle equal to the desired helix angle of the gear being ground. By proper angular adjustment of the carriage 31 gears may be ground having teeth disposed at any predetermined helix angle. The master gear 45 and

master rack 50, however, preferably have teeth of the spur type. The master gear is, however, equal in pitch diameter and number of teeth to the gear being ground so that the rolling action of the gear being ground W induced by rolling the master gear 45 is identical.

The indexing member 55 is slidable horizontally within an extension 60 of a vertically adjustable bracket 61. The bracket 61 is adjustable vertically upon ways formed on a vertical extension of the rotary adjustable carriage 31 (see Fig. 3). To effect this adjustment a hand wheel 61a is provided operating a screw 62a. To actuate the indexing member 55 a vertically disposed member or piston 62 is provided within the bracket 61, its extended upper end being connected to one arm of a bell crank lever 63 pivoted to the bracket. The operation of member 62 will be further described in connection with the hydraulic system. The other arm of the bell crank lever 63 is connected to one end of the indexing member 55. Fluid admitted to opposite ends of the cylinder within which vertical piston 62 operates, as will be described presently, moves the indexing member 55 horizontally a predetermined distance along the ways of the supporting member 60. To limit this movement in the indexing direction an adjustable stop 64 may be provided in the path of movement of member 55 so that the amount of rotary or indexing movement given the gears 45 and W may be regulated.

The arm 51 supporting master rack 50 is pivotally mounted upon the bracket 61 at one end on an eccentric bearing surface formed on a short transverse shaft 65. By oscillation of this shaft 65 the eccentric bearing therefor causes the arm 51 to be adjusted slight amounts horizontally to the left or right, thus in effect causing slight rotation of the master gear 45 and gear W being ground upon their axes. By this means the gear W being ground can be very slightly rotated during adjustment or during the grinding operation to properly contact the abrasive wheel 13 with opposite sides of the teeth being ground. In order to effect this adjustment of the machine an arm 66 is secured to or formed integrally with the shaft 65, spring pressed in one direction by a spring plunger 67. The arm 66 and shaft 65 may be manually oscillated in the opposite direction by a screw 68 bearing against the side of the arm 66, the position of which may be varied by a hand wheel 69. A spring 70 housed within the bracket 61 bears against the upper surface of and normally forces the arm 51 carrying the master rack 50 downward against the master gear, thus holding the rack 50 in contact with the master gear 45. Referring now to the diagram shown in Fig. 6, the hydraulic system will now be described.

The mechanism for admitting fluid to the cylinder 25 to operate the ram 12 includes preferably a distributing valve 80 actuated by means of a pilot valve 81. A lever 82 attached pivotally at one end of the pilot valve 81 has oppositely extending arms provided with rollers at their free ends. Adapted to contact with these rollers to oscillate the lever 82 and thus actuate the pilot valve 81 in opposite directions are adjustable dogs or cams 83 on the side of the ram 12. For convenience a hand lever 84 is provided on the lever 82 for manual operation of the pilot valve 81 at any time. By clamping the dogs 83 in adjusted positions along the side of the ram 12 the ram may be reversed at different points to vary its stroke to any desired length and between any desired positions. The construction and operation of the pilot valve 81 and distributing valve 80 for effecting different strokes of the ram 12, and the means for controlling its speed of operation will presently be described.

There will also be described the means for reciprocating the table 35, actuating the indexing member 55 and raising and lowering the master rack 50. The system to be described coordinates the operation of the different actuated members to perform grinding operations upon the gear W within a single tooth space while the gear W is slowly rolling past the wheel 13 by movement of the table 35 and while the wheel 13 is being rapidly reciprocated by its ram 12. Upon completion of the grinding of any one tooth space, the master rack 50 is disengaged from the master gear 45, the indexing member 55 advanced, the master rack re-engaged with the master gear and grinding of a second tooth space begun. These grinding and indexing movements continue alternately until the gear is completely ground. Means to control length of movement and the speed of the table 35 is provided hydraulically so that the gear W may be rolled very slowly during the actual grinding and more rapidly to move the gear laterally of the wheel to permit indexing and also loading and unloading, an extreme lateral position being provided for that purpose, dogs for these purposes being adjustable on a front surface of the table 35. At the completion of grinding of all teeth of a gear the machine may be stopped automatically. The diagram shown in Fig. 6 will now be referred to.

The mechanism for reciprocating the table 35 to effect movement of the gear blank W past the wheel 13 and to index the gear to successively present different tooth spaces to the wheel 13 includes a main control pilot valve 113 having a lever 114 thereon adapted to be oscillated by adjustable and fixed dogs on the table 35 to control the length of stroke, speed and points of reversal of movement of the table 35. This pilot valve 113 effects movement of the table 35 by means of a table reverse valve 115 having intermediate and extreme positions, which admits oil to opposite ends of a cylinder 36 in which a piston 37 attached to and moving with the table 35 is provided.

There is also provided an index valve 117 controlling the admission of oil to cylinders within which pistons 62 operating the indexing rack slide and piston 146 raising and lowering the master rack 50 are disposed.

There are also a manually moved valve 111 for effecting rapid traversing movements of the table 35 independently of the indexing operation and while the ram 12 is not moving and an automatic stop valve 137 arranged to stop the entire machine upon completion of the grinding of a gear and unlatching of an automatic knockoff valve 130. There may also preferably be provided a high speed valve 116 so that the table 35 may be moved rapidly throughout its movement during the setting up operation.

The above include the principal members of the hydraulic system for the machine and their method of controlling the operative parts of the machine. These members are operated in accordance with a predetermined cycle which will now be described. To simplify the diagram as much as possible parts are shown as all being in a single plane.

Two separate hydraulic systems are employed

for effecting the functions of the machine. One system operates the ram 12 to reciprocate the wheel 13 past the work W and is shown in the upper right hand portion of the Fig. 6, representing a diagram of the hydraulic system. This ram system controls the speed, reversal and length of stroke of the ram 12. This part of the hydraulic system takes its supply of oil from a common tank (not shown) but has its individual circulating pump (also not shown). This is for the purpose of preventing rapid changes of pressure within the hydraulic system for moving the table 35 mounting the gear being ground due to the rapid reversals of the heavy ram 12. These variations of pressure would affect the proper and accurate functioning of the second hydraulic system.

The second or table moving hydraulic system for effecting generating movements of the work occupies the remainder of the diagrammatic drawing and controls the speed, reversal and length of stroke of the work support and the indexing mechanism, that is, all movements of the gear being ground. Also by means of a special or supplementary valve this system starts and stops reciprocation of the ram 12 by opening and closing a control valve within the hydraulic system for the ram. This second or generating system has its own circulating pump but takes its oil from and exhausts it to a common tank.

In the diagrammatic view the valves are all shown in the positions they occupy when the grinding wheel 13 is passing through a tooth space of the gear W being ground, the only parts moving in either hydraulic system are therefore the piston 37 moving the table or support 35 for the gear W and the piston 26 for the ram 12.

Oil enters the generating system at 110 and passes through a branch 110a to the automatic knockoff valve 130 and holds the stop valve 88 for the ram 12 toward the right which is its open position. Oil enters the ram hydraulic system from a suitable pump (not shown) at 85 and passes through the ram speed control valve 86, the ram automatic stop valve 88, the ram reverse valve 80 and through connection 90 to move the ram piston 26 and the ram 12 operated thereby toward the right. Simultaneously oil exhausts from the right end of the ram piston cylinder through 91 and the ram reversing valve 80 to the tank. The ram speed control valve 86 may be used primarily for manually controlling the speed of the ram 12 during preliminary adjustment and setting up of the machine, during normal operation, however, this valve is in its fully open position. To control the speed of the ram 12 during the grinding operation the spring relief valve 87 is used shown incorporated within the manual valve 86. The means for controlling the pressure of the spring is not shown but by varying the compression of this spring the amount of oil admitted to the ram system may be varied. Also the oil may be exhausted to the tank through this relief valve 87 when the manual valve 86 is partially closed as during the setting-up operation.

At the end of the ram movement to the right the ram pilot valve 81 by means of an adjustable dog 83 on the ram 12 and the lever 82 connected to this pilot valve is moved to the right from its central or neutral position. Oil may then flow through the ram reverse valve throttle 97, the ram pilot valve 81, thence through 95 to the right end of the ram reverse valve 80 and moves this valve to the left, oil at the left end of this valve exhausting through 94, the ram pilot valve 81, and pipe 96 to the tank.

To maintain the pilot valve 81 normally and resiliently in its neutral and central position springs 100 and 101 may be employed helically disposed upon stem extensions at opposite ends of the valve. Spring 100, shown in Fig. 8, forces valve 81 toward the left as it is disposed between an abutment on the valve casing and a collar 102 pinned to the stem extension. This action tends to force a sleeve 104 pinned to the right end of the stem extension toward and against a collar 103 and away from a sleeve 105 threaded into the casing for the valve. The collar 103 is slidably mounted on the stem extension and engages the spring 101. Spring 101, however, opposes movement of the valve to the left. Spring 101 at the right hand end of the valve is stronger than the spring 100 and maintains the valve 80 at the right as far as permitted by sleeve 105. By adjusting the member 105 axially relative to the valve casing and with the right hand spring 101 exerting a stronger force upon the valve 81 than spring 100 the neutral position of the valve can be accurately maintained at any predetermined position. From this position the valve 81 may be operated in either direction by the lever 82 and cams 83 as above described and, upon release of the lever 82 by cam 83 will be returned immediately to its neutral position.

To control the speed of movement of the ram reverse valve 80 and thus control the length of time used to bring the ram 12 to a full stop and accelerate it to full speed in the opposite direction, a reverse valve throttle 97 is used. Any form of manually adjusted throttle valve for this purpose may be employed as is shown diagrammatically in Fig. 6. As the ram reverse valve 80 moves to the left, the oil flow to it from pipe 90 changes to an exhaust, the flow to it taking place through pipe 91 to the ram piston and moves this piston 26 to the left. The ram pilot valve 81 promptly moves back to neutral or central position under the influence of the balanced springs referred to above and remains in this neutral position until the end of the ram movement in the opposite direction; thereupon the pilot valve 81 is moved in the opposite direction, that is, to the left. Oil then flows through the ram reverse valve throttle 97, pipe 93, the ram pilot valve 81 and pipe 94 to the left end of the ram reverse valve 80, moving it to the right. In the meantime oil may exhaust through pipe 95, the ram pilot valve 81 and pipe 96 to the tank. Oil flows through pipe 85 and the ram reverse valve 80 in the original direction and the piston 26 and ram 12 then move again to the right. The reciprocation of the ram 12 is continued by the above described hydraulic circuit until operation of the automatic stop valve 88, the controlling of which will be described later.

Referring now to the operation of the generating hydraulic system, oil is flowing from a pump (not shown) through pipe 110 to the table automatic stop valve 137, thence through the grinding speed control valve 124, pipe 120 to the main control pilot valve 113, pipe 121, the table reverse valve 115 and pipe 122 to the right end of the table cylinder 36, thus moving this piston 37 and its table 35 or support to the left at grinding speed. Oil from the left end of the table cylinder exhausts through pipe 123, the table reverse valve 115, and pipe 115a back to the tank.

In the positions of the valves shown in the diagrammatic figure the oil in branch 142 is in-

operative. The oil in branch pipes 142 and 143, the indexing valve 117 and in pipe 144 serves to hold the indexing rack piston 62 down. The oil in branch of pipe 110 to valve 111 is inoperative as well as that in branches to the main control pilot valve 113 and automatic knockoff valve 130. At the end of the table piston movement to the left the main control pilot valve 113 by means of the adjustable dog on the table 35 and the lever 114 connected to the valve 113 is moved partially to the left from its central or neutral position. Oil then flows through the automatic stop valve 137, the main pilot valve 113 and the reverse valve 115 to the table cylinder 36. This partial movement of the pilot valve lever 114 and its valve 113 allows oil to flow to the table cylinder 36 through pipe 121a in addition to that going through the grinding speed control valve 124, and the table 35 therefore moves rapidly to the left to the indexing and reversing position. As soon as the table 35 reaches its reversing position another dog on the table moves the pilot valve 113 further to the left. Oil then flows through connections 121a to the pilot valve 113 and to the right end of the table reverse valve 115 through connection 122a moving this valve to the left. From the left end of this valve 115 oil exhausts through pipes 123a and 124a to 115b and to the tank. The table reverse valve 115 moves to the left only to a neutral position, further movement being prevented by the reverse valve lock bolt 157. When the reverse valve 115 is in this neutral position oil cannot flow to either end of the table operating cylinder 36, thus causing the table to remain in fixed position. Oil then flows through connections 141 and 140 to the left end of the index valve 117 moving it to the right which moves the index return roll 125a up, the index return dog 126a being out of contact therewith at this time. Oil then flows through connections 143, 151 and 147 to the lower end of the rack lifting piston 146, moving this piston up and lifting the master rack 50 from intermeshing relation with the master gear 45, the oil from above the piston 146 exhausting through connections 154 and 154a to the tank. As soon as the rack lifting piston 146 reaches the upper end of its motion a port to connection 150 is uncovered which allows oil coming through connection 150 to flow through connections to the lower end of the cylinder for the index rack piston 62. This piston 62 moves up and through the lever connected to its upper end, moves the index rack slide 55 to the right, indexing the master gear 45 and parts associated therewith. Oil above the piston exhausts through connections 144 and 145a.

As soon as the piston 62 for the indexing rack reaches the upper end of its motion it uncovers a port and connects pipes 142 and 154. Oil then passes from 142 through 154 to the space above the rack lifting piston 146. This piston 146 then moves down, the oil below the piston exhausting through 147 and 154a to the tank. As soon as the piston 146 reaches its lowermost position it uncovers connection 158, thus allowing oil from connection 154 to flow through 159 and to move the piston 160 for the ratchet 161 down to index the automatic knockoff ratchet wheel 132 one or more teeth. Simultaneously oil flows through an extension of 158 to lift the reverse valve lock bolt 157 so that the reverse valve 115 may be moved. As soon as the lock bolt 157 has been lifted to disengage the valve 115 oil pressure at the right end of the table reverse valve moves this valve 115 to its extreme left hand position.

With the reverse valve 115 at its left hand position oil flows through connection 110b directly into and through the pilot valve 113, thence through 121 and 123 so that the table 35 moves rapidly to the right. From the right end of the table moving piston 37 oil exhausts through connections 122 and the valve 115 to 115b. As soon as the table 35 starts to the right the main control pilot valve 113 moves back to its intermediate left hand position so that oil may be supplied to connection 123 for rapid traversing movement past the automatic stop valve 137 and connections 121a and 121 until the table 35 reaches the grinding position. The pilot valve 113 then moves to its neutral position, movements toward neutral positions of this pilot valve being caused by the balanced springs at opposite ends thereof. With the pilot valve 113 in its neutral position oil cannot flow through high speed connection but flows through the grinding speed control valve 124 only and the table therefore continues its movement to the right at reduced grinding speed.

As the table passes through the central portion of its movement the index return dog 126a contacts with the index return roll 125a and depresses this roll, thus moving the index valve to the left. Oil flows through connections 143 and 144 moving the indexing rack piston 62 down and the index rack slide to the left against an adjustable stop. This movement of the piston 62 restores the index slide to its initial position and takes place while the index slide rack 56 is out of contact with the master gear 45. The movement of the slide 55 carrying rack 56 is limited to one circular pitch of the master rack 50 but the indexing piston 62 moves far enough downward to cover the port of connection 142 and uncover port of connection 154a to the tank. With the piston for the index slide in its lowermost position the reverse valve lock bolt 157 is moved downward by its spring as the oil under it exhausts through connections 158, 154 and 154a. The ratchet operating piston 160 is moved upward by its spring as the oil above it is released and exhausts through 159, 158, 154 to 154a. The table continues to move to the right and the cycle of reversing and indexing just described is repeated, corresponding adjustable dogs 114b on the table 35 being used to reverse the table movement from the opposite end of its stroke.

The oil flow at either stroke is the same except that when the main control pilot valve 113 is functioning to the right of its neutral position right hand connections are used in place of left hand connections and the pressure lines become exhausts and vice versa, fluid exhausting through 122a, 122b and 115b. The table reverse valve 115 thus moves to the right instead of the left, causing the table after the indexing movement is completed to reverse and return to the left, thus depressing the index return roll 125a ready for the next index and for completing the cycle. By use of an index return dog 126a which will depress the roll 125a only when the table is moving in one direction, the index valve 117 may be moved to the left or operative position but once during a complete cycle. Until the index valve 117 is moved to the left the index rack piston 62 will not move down, the reverse valve lock bolt 157 cannot move down and the ratchet operating piston 160 cannot move up. The table 35 will therefore reverse without pause and indexing will not take place. The same space in the gear in that case will be

ground twice in succession, once at each movement of the table in each direction.

Grinding of the gear W will continue and indexing will take place at either or both ends of the table travel as may be desired until all teeth have been ground. As the rack lifting piston 146 reaches the lower end of its movement completing an indexing movement after the last tooth space has been ground, a pin 133 on the automatic knockoff ratchet wheel 132 will trip its latch 131 holding the valve 130 to the left and allow its spring to move it to the right. Oil then flows through 110a and 135 moving the ram stop valve 88 to the left and stopping the ram promptly in any position, oil at the left of the valve 88 exhausting through 137a and the valve 30. Oil also flows through 136 to move the high speed valve 116 to the left. Oil also flows through another branch of 136 to move the index return roll 125a endwise so that it does not engage the index return dog 126a. Another circuit for oil extends through a branch connection of 136 to move the table automatic stop valve 137 to the left. With this stop valve 137 in its position to the left oil cannot reach the table piston 37 and thus the table 35 remains stationary while being maintained in its indexing position.

From this condition both of the hydraulic systems can be put into operation for grinding again by manually moving the automatic knockoff valve 130 to the left until the latch holds it again. The index return roll 125a, the table automatic stop valve 137 and the high speed valve 116 will then move to their former positions under pressure of their springs, oil will exhaust from their opposite ends through connections to the tank. The ram automatic stop valve 88 will move to the right, starting the ram 12 again in motion by oil flowing in connection 89 to the ram reverse valve 80, the oil at the right end of the valve 88 exhausting through connection 135 through the valve 130 to the tank.

If after the automatic knockoff valve 130 has moved to the right, it is desired to inspect or gage the gear W being ground, or remove it from the work supports 41 and 46 and replace it with another gear, the rapid traverse valve 111 is manually moved to the right by means of the lever 112. Oil which was prevented from reaching the table piston by the closing of the table automatic stop valve 137 will now flow through 110b from the opened rapid traverse valve 111 and connection 121 and from that point as above described. As the oil does not have to flow through the grinding speed control valve 124 the table 35 will move at high speed regardless of the position of the main control pilot valve 113. The index return roll 125a being out of contact with the index return dog 126a, no indexing will take place during this extended movement.

By arranging one set of table dogs so that they will not contact with the lever 114 operating the main control pilot valve, the table 35, when travelling in one direction, will continue by the dogs to the inspection or loading position where it will be stopped by the rapid traverse valve 111 being moved to the left by means of its lever 112 striking one of its dogs.

To start operation of the machine again the automatic knockoff valve 130 is moved to the left to be retained by its latch 131. The table 35 will move a very short distance in the direction it was moving when stopped and a fixed dog on the table 35 will reverse the table 35 by moving the main control pilot valve 113 so that the table 35 moves back into grinding position. The ram 12 will again start and all valves will move back to their initial positions and resume their normal movements during grinding operation.

In order to facilitate setting up work in the machine, the automatic knockoff valve 130 may be unlatched manually and the rapid traverse valve 111 used to control the table 35 movements. Under these conditions the ram 12 will not be reciprocated. The table 35 will be operated at rapid traverse speed only and the indexing mechanism will not operate.

What I claim is:

1. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to actuate said ram, an angularly adjustable carriage, gear supporting and actuating means on said carriage to effect a rolling movement of said gear past said wheel, means to index said gear about its axis of rotation, and hydraulic means to reciprocate said actuating means in any angular position of said carriage.

2. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to reciprocate said ram horizontally at predetermined speeds and strokes, a carriage angularly adjustable about a vertical axis, gear supporting and actuating means on said carriage to effect a rolling movement of said gear past said wheel, means to index said gear about its axis of rotation, and hydraulic means to reciprocate said supporting means to effect said rolling movement in any angular position of said carriage.

3. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to actuate said ram, an angularly adjustable carriage, gear supporting means on said carriage, actuating means for said gear on said carriage to effect a rolling movement thereof past said wheel, hydraulic means to index said gear about its axis of rotation, and hydraulic means to reciprocate said supporting means in any angular position of said carriage.

4. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to actuate said ram, an angularly adjustable carriage, gear supporting and actuating means on said carriage to effect a rolling movement of said gear past said wheel, hydraulic means to index said gear about its axis of rotation, and hydraulic means to reciprocate said supporting means upon said carriage in any angular position of said carriage.

5. A gear tooth grinding machine comprising in combination, a base, a wheel carrying ram mounted for reciprocatory movement thereon upon a fixed axis, a rotatably mounted wheel thereon, a gear supporting member for effecting rolling movement of said gear past said wheel at any predetermined angle to the axis thereof, hydraulic means to reciprocate said ram, hydraulic means to reciprocate said gear supporting member, a pilot valve controlling fluid admission to said hydraulic system, dogs on said ram for operating said pilot valve, and resilient means maintaining said pilot valve in neutral position when released from said dogs.

6. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to actuate said ram, an angularly adjustable carriage,

gear supporting and actuating means on said carriage to effect a rolling movement of said gear past said wheel, hydraulic means to index said gear about its axis of rotation, hydraulic means to reciprocate said supporting means upon said carriage in any angular position of said carriage and means preventing operation of said supporting and actuating means during operation of said indexing means.

7. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to actuate said ram, an angularly adjustable carriage, gear supporting and actuating means on said carriage to effect a rolling movement of said gear past said wheel, hydraulic means to index said gear about its axis of rotation, hydraulic means to reciprocate said supporting and actuating means upon said carriage in any angular position of said carriage, means preventing operation of said supporting and actuating means during operation of said indexing means, and means to start operation of said ram upon completion of said indexing movement.

8. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to actuate said ram, an angularly adjustable carriage, gear supporting and actuating means on said carriage to effect a rolling movement of said gear past said wheel, hydraulic means to index said gear about its axis of rotation, hydraulic means to reciprocate said supporting and actuating means upon said carriage in any angular position of said table, means preventing operation of said ram during operation of said indexing means, and means preventing operation of said supporting and actuating means during operation of said indexing means.

9. A gear tooth grinding machine comprising in combination, a base, a reciprocatory wheel supporting ram thereon, hydraulic means to actuate said ram, an angularly adjustable carriage, gear supporting and actuating means on said carriage to effect a rolling movement of said gear past said wheel, hydraulic means to index said gear about its axis of rotation, hydraulic means to reciprocate said supporting and actuating means upon said carriage in any angular position of said carriage, means preventing operation of the actuating means for said gear during operation of said indexing means, and means to again start said actuating means upon completion of said indexing operation.

10. A gear tooth grinding machine comprising in combination, a base, a wheel carrying ram mounted for reciprocatory movement thereon, a rotatable wheel on said ram, an angularly adjustable carriage on said base, a table slidable on said carriage, and gear mounting means on said table for effecting rotation of said gear upon its axis, means to effect rolling of said gear past said wheel, and hydraulic means to reciprocate said table in any angular adjustment of the carriage whereby the gear may be rolled past said wheel with its axis at any predetermined angle, and hydraulic means to reciprocate said ram.

11. A gear tooth grinding machine comprising in combination, a base, a wheel carrying ram mounted for reciprocatory movement thereon, a rotatable wheel on said ram, an angularly adjustable carriage on said base, a table slidable on said carriage, and gear mounting means on said table for rotation of said gear upon its axis, means to effect rolling of said gear past said wheel, hydraulic means to reciprocate said table in any angular adjustment of the carriage whereby the gear may be rolled past said wheel with its axis at any predetermined angle, hydraulic means to reciprocate said ram during actuation of said table, and hydraulically controlled means to stop movement of said ram and table when said table has completed a predetermined number of strokes and reaches the end of its stroke in one direction.

12. A gear tooth grinding machine comprising in combination, a base, a wheel carrying ram mounted for reciprocatory movement thereon, a rotatable wheel on said ram, an angularly adjustable carriage on said base, a table slidable on said carriage, and gear mounting means on said table for rotation of said gear upon its axis, means to effect rolling of said gear past said wheel, and hydraulic means to reciprocate said table in any angular adjustment of the carriage whereby the gear may be rolled past said wheel with its axis at any predetermined angle, hydraulic means to reciprocate said ram, and hydraulic means to index said gear at the end of the movement of said table in either direction.

HUBERT D. TANNER.