May 3, 1927.

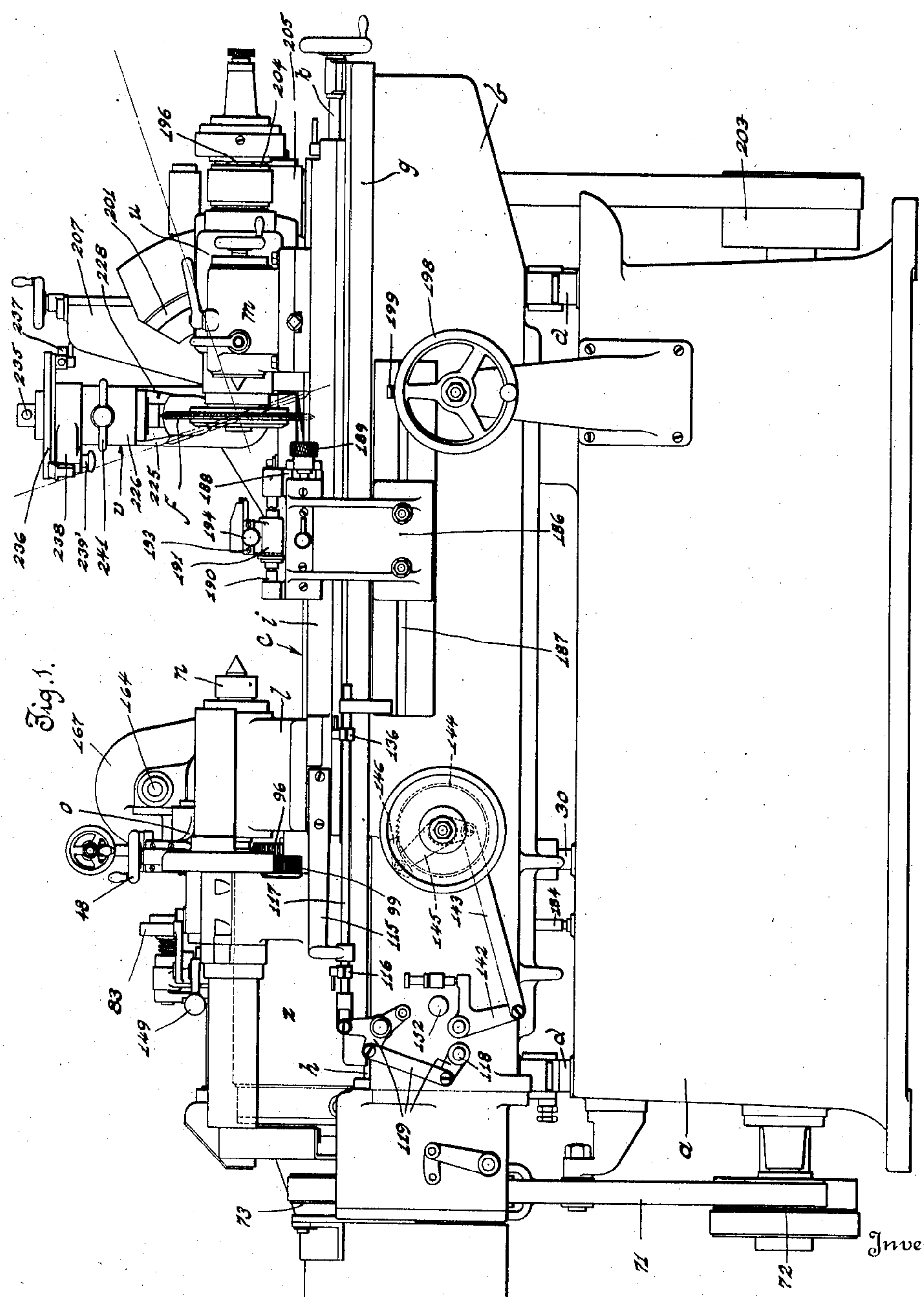
B. M. W. HANSON

1,627,090

METAL WORKING MACHINE

Filed Oct. 10, 1922

11 Sheets-Sheet 1



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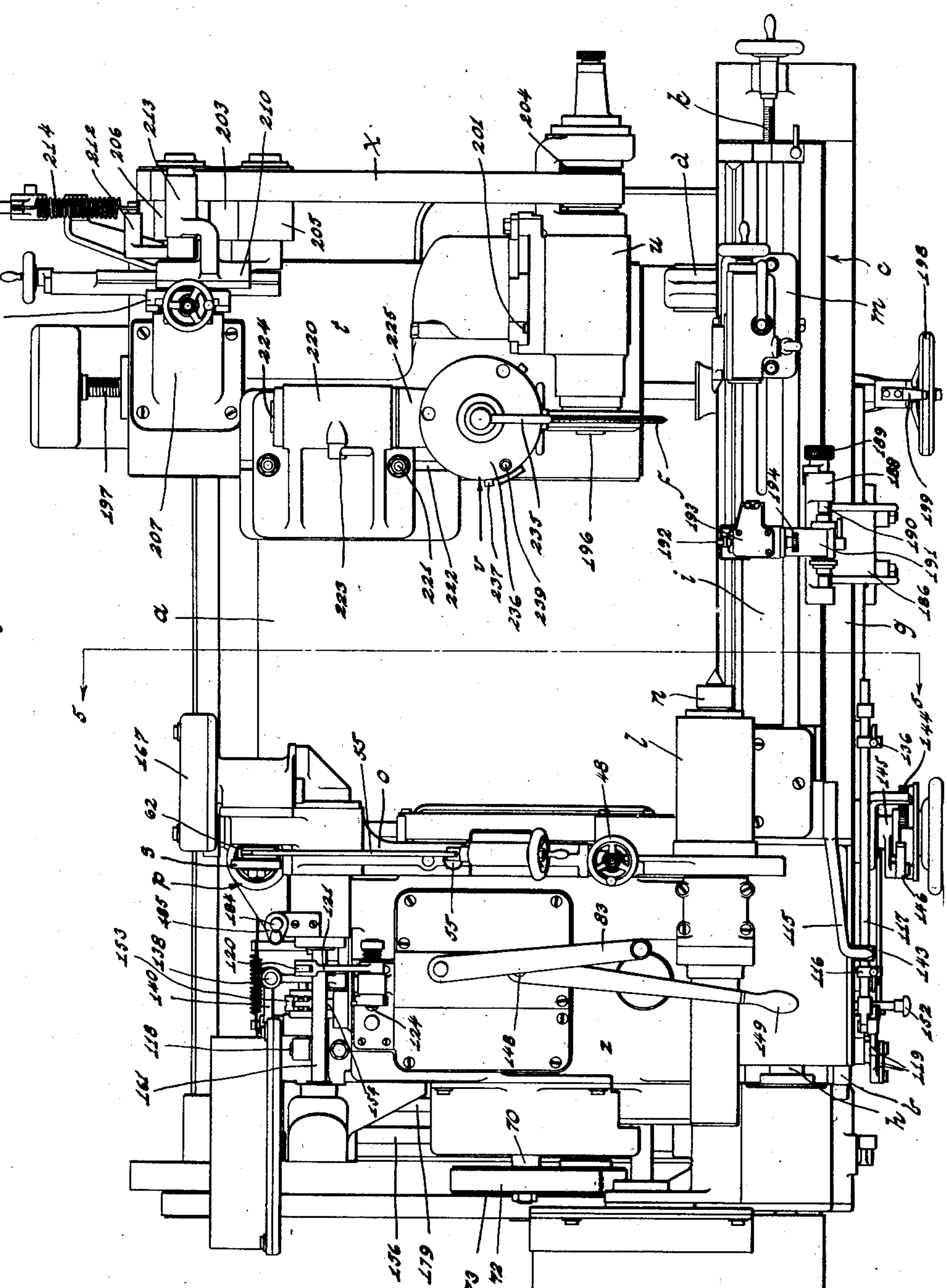

Fig. 2.

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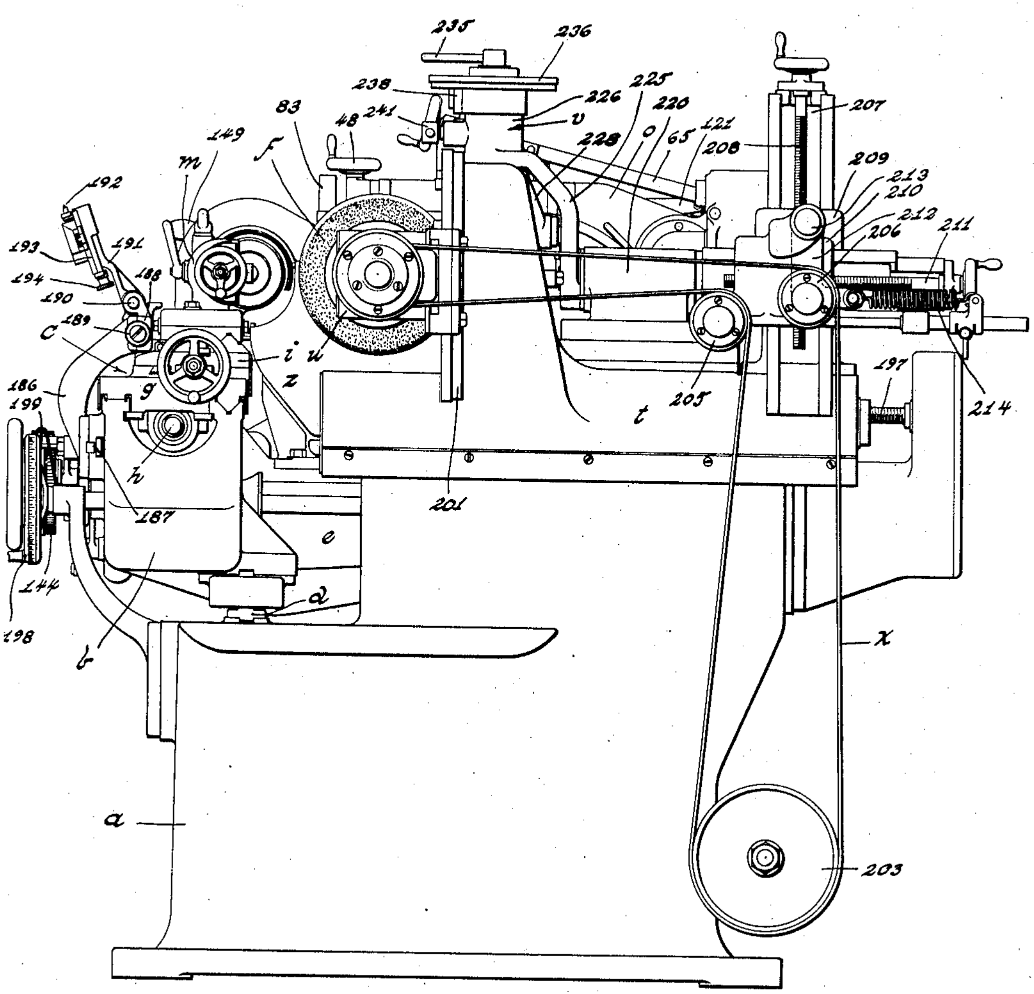
Fig. 3.

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METAL WORKING MACHINE

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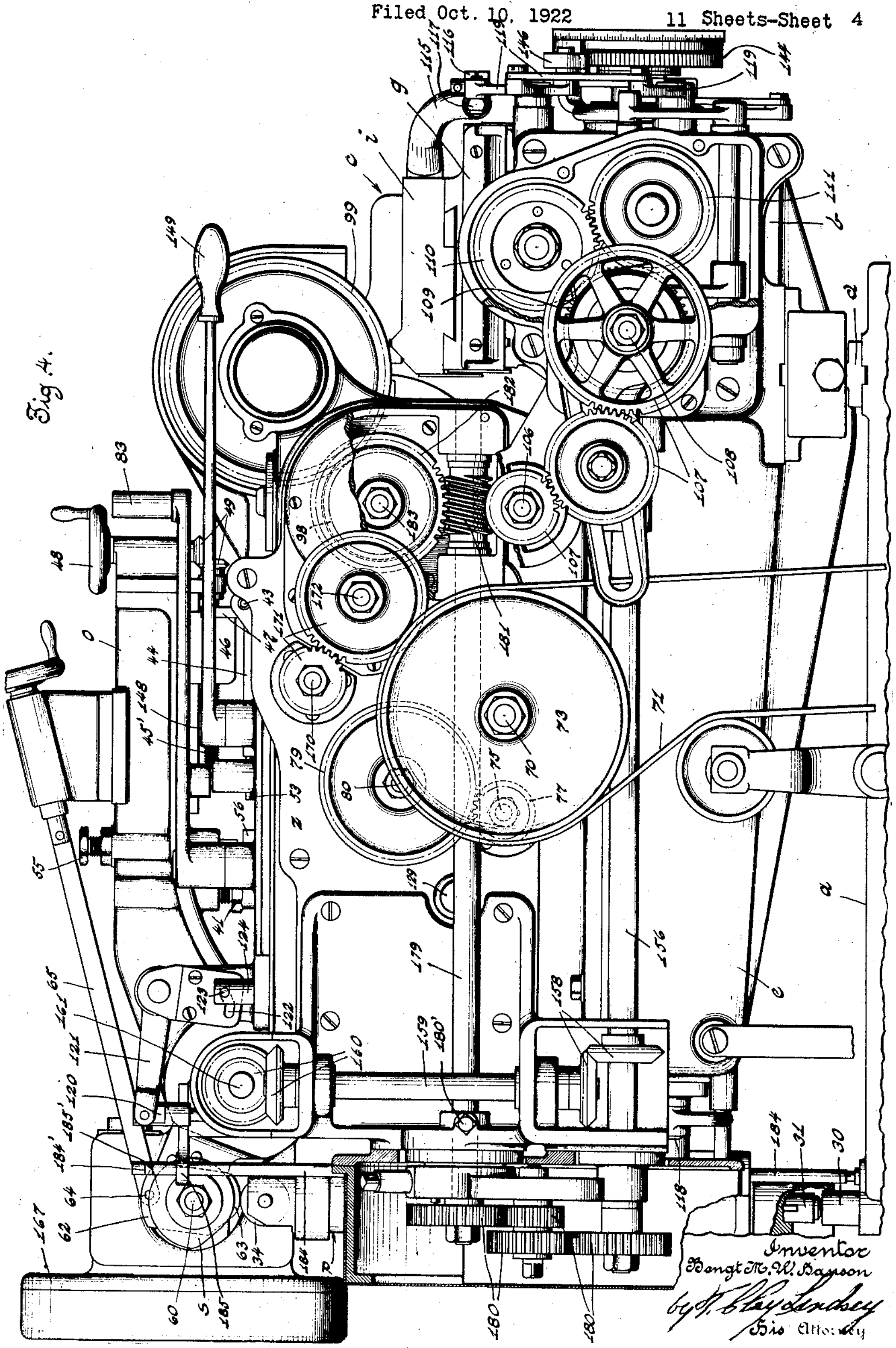

Fig. 4.

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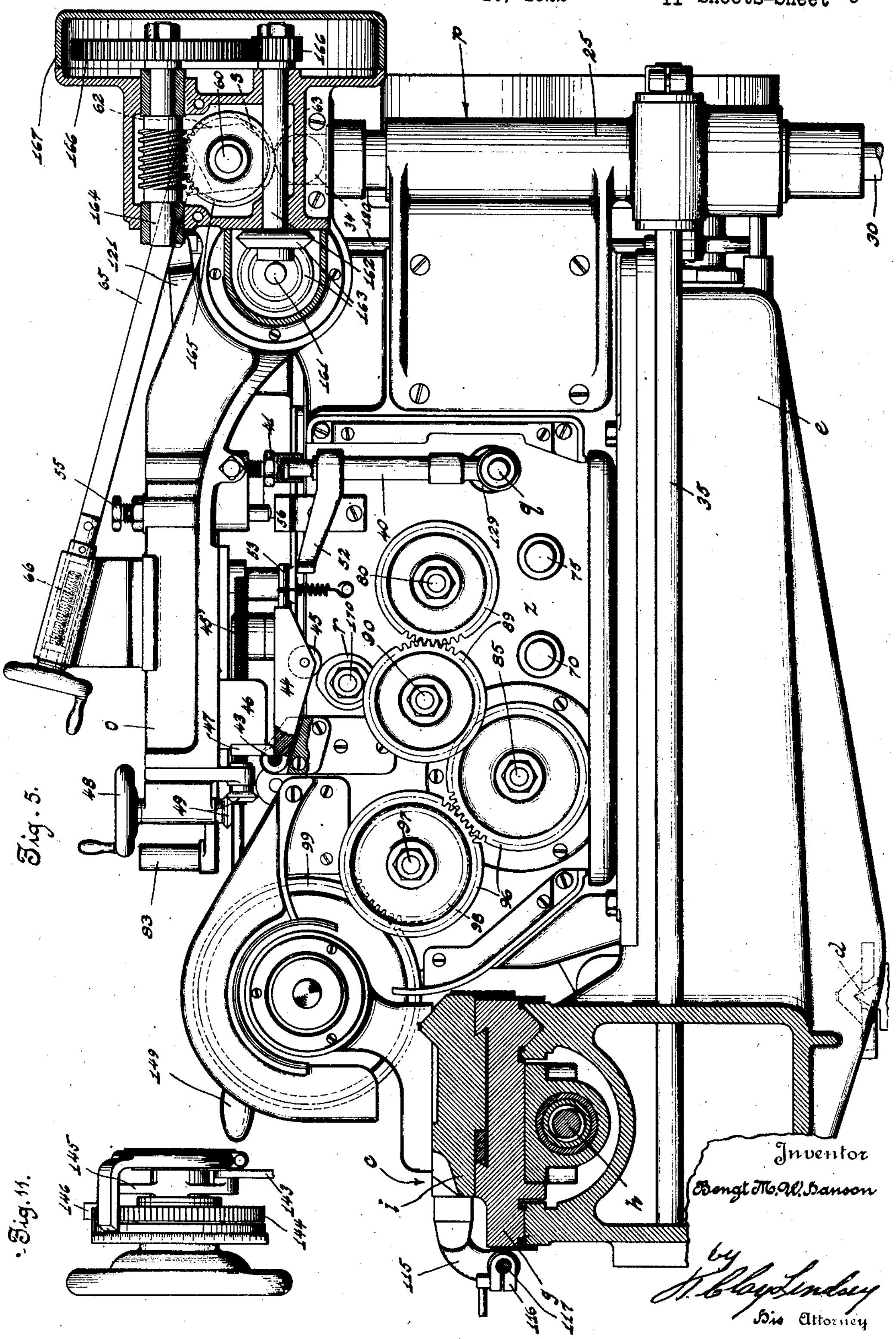

Fig. 5.

Fig. 11.

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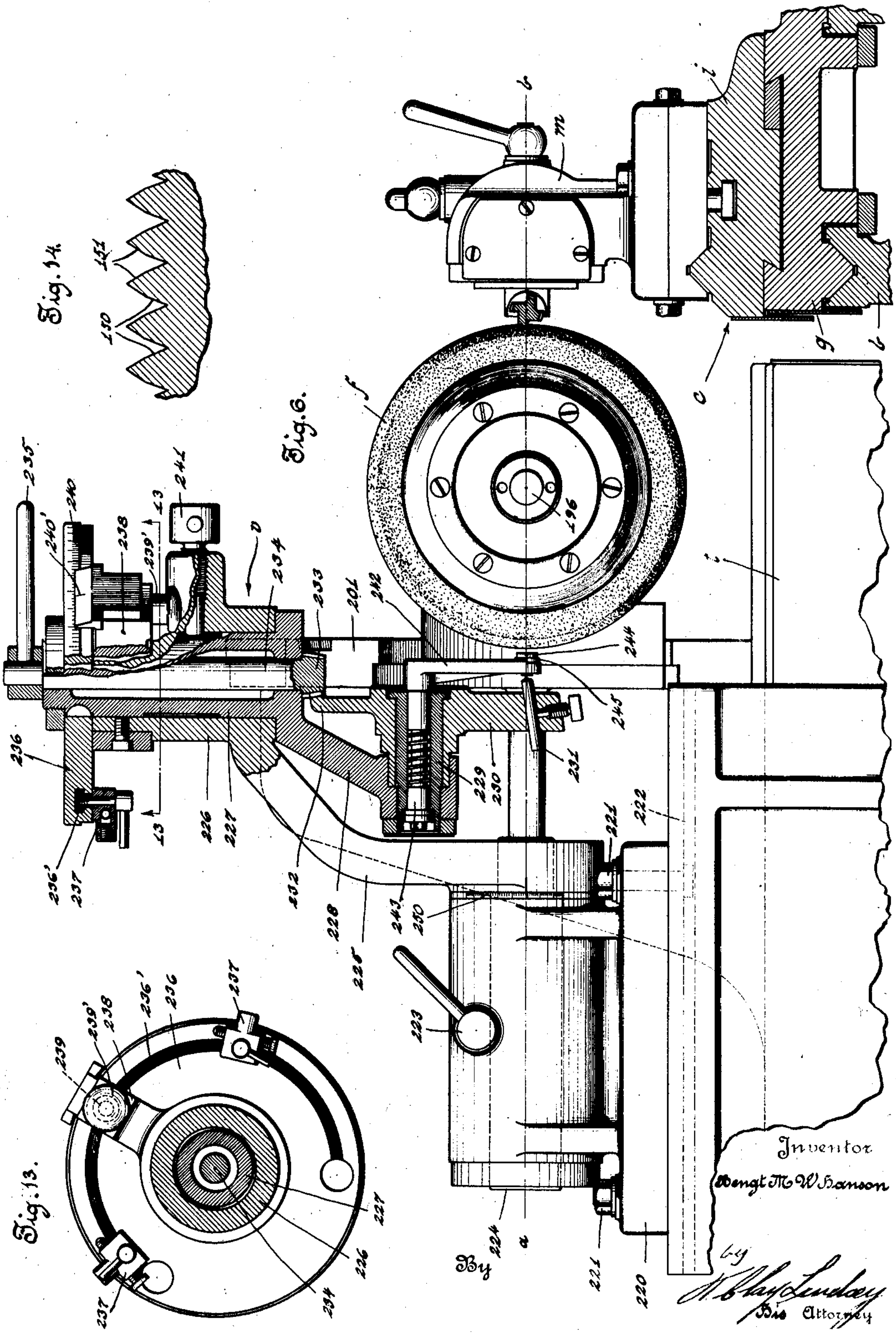


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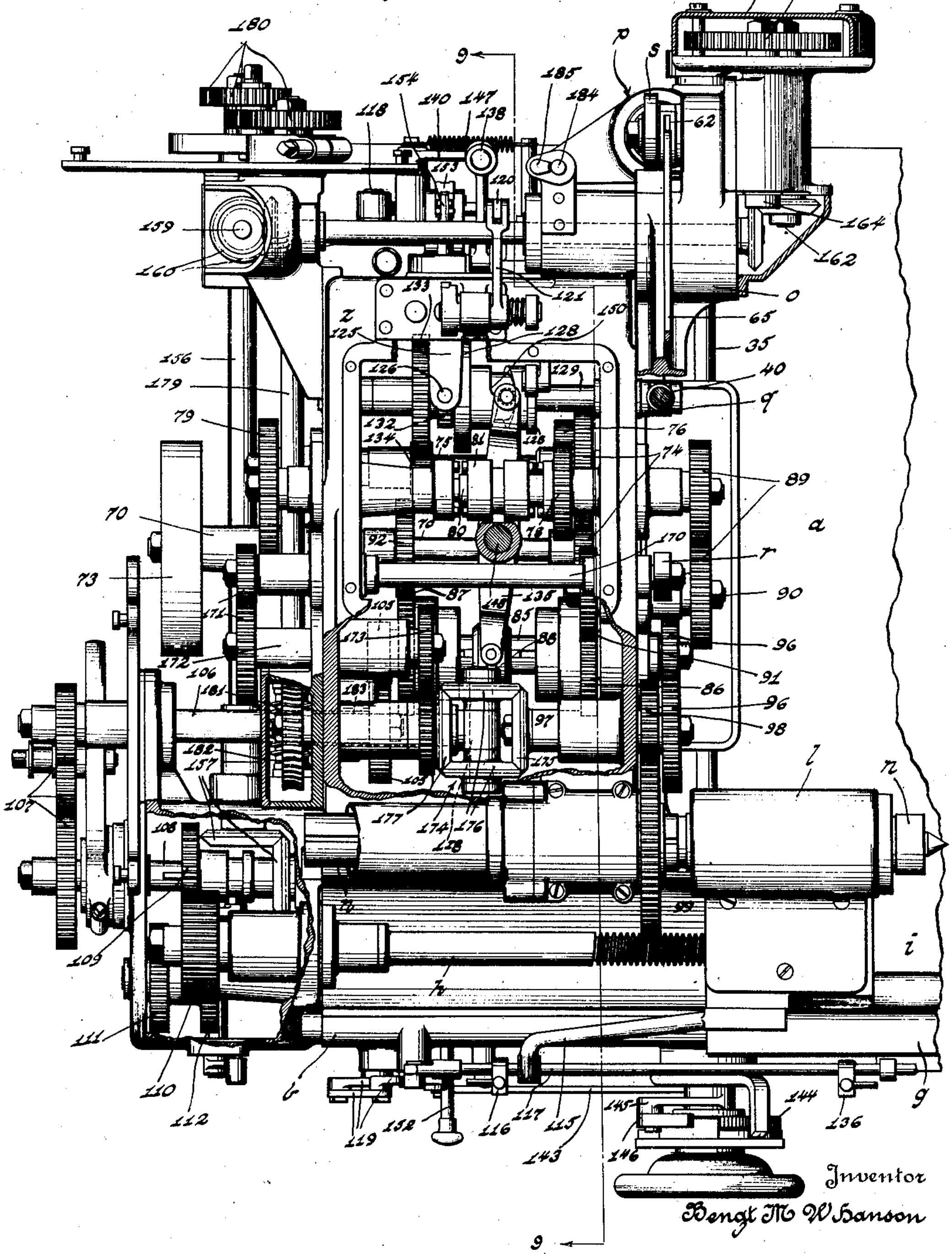
Fig. 7.



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METAL WORKING MACHINE

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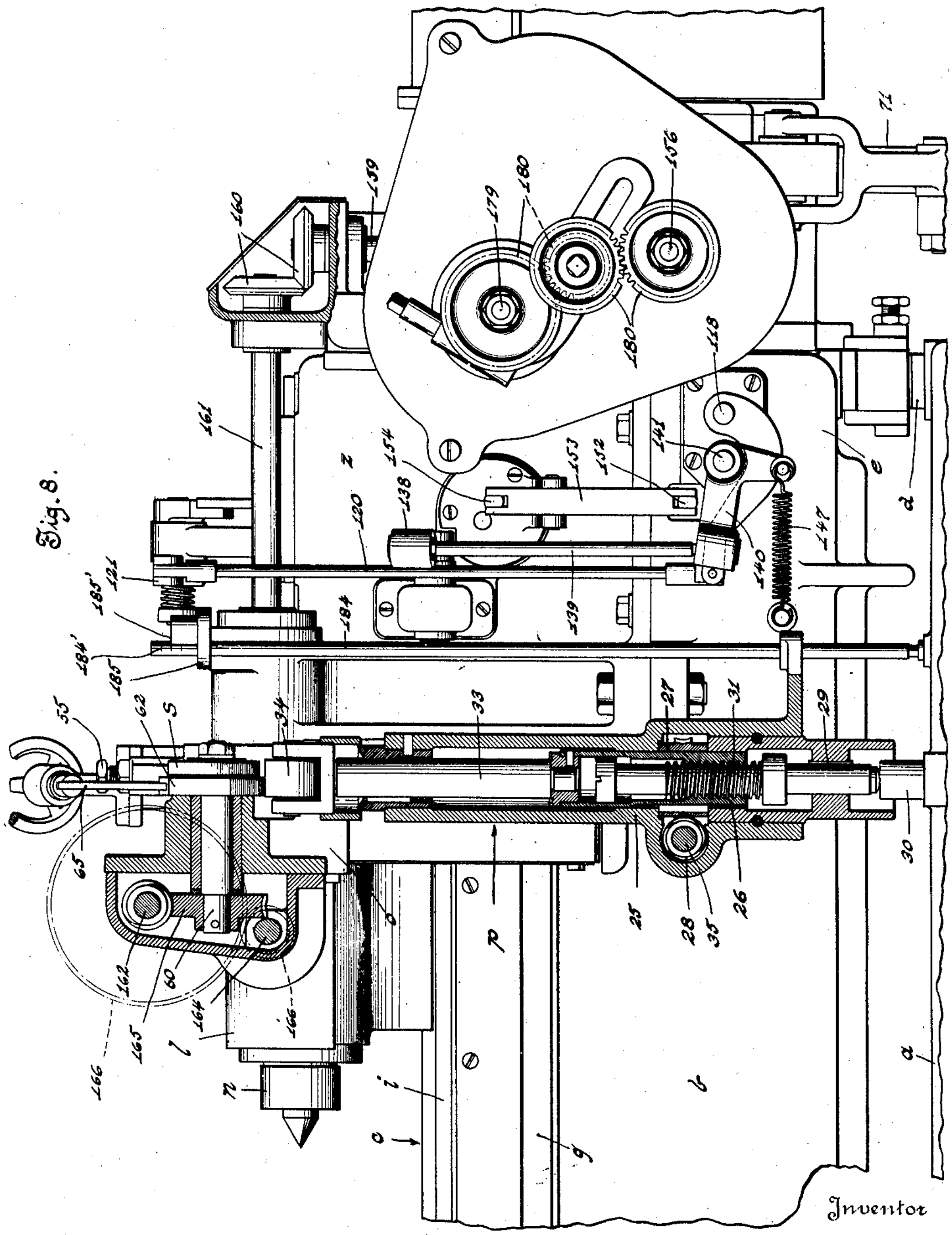

Fig. 8.

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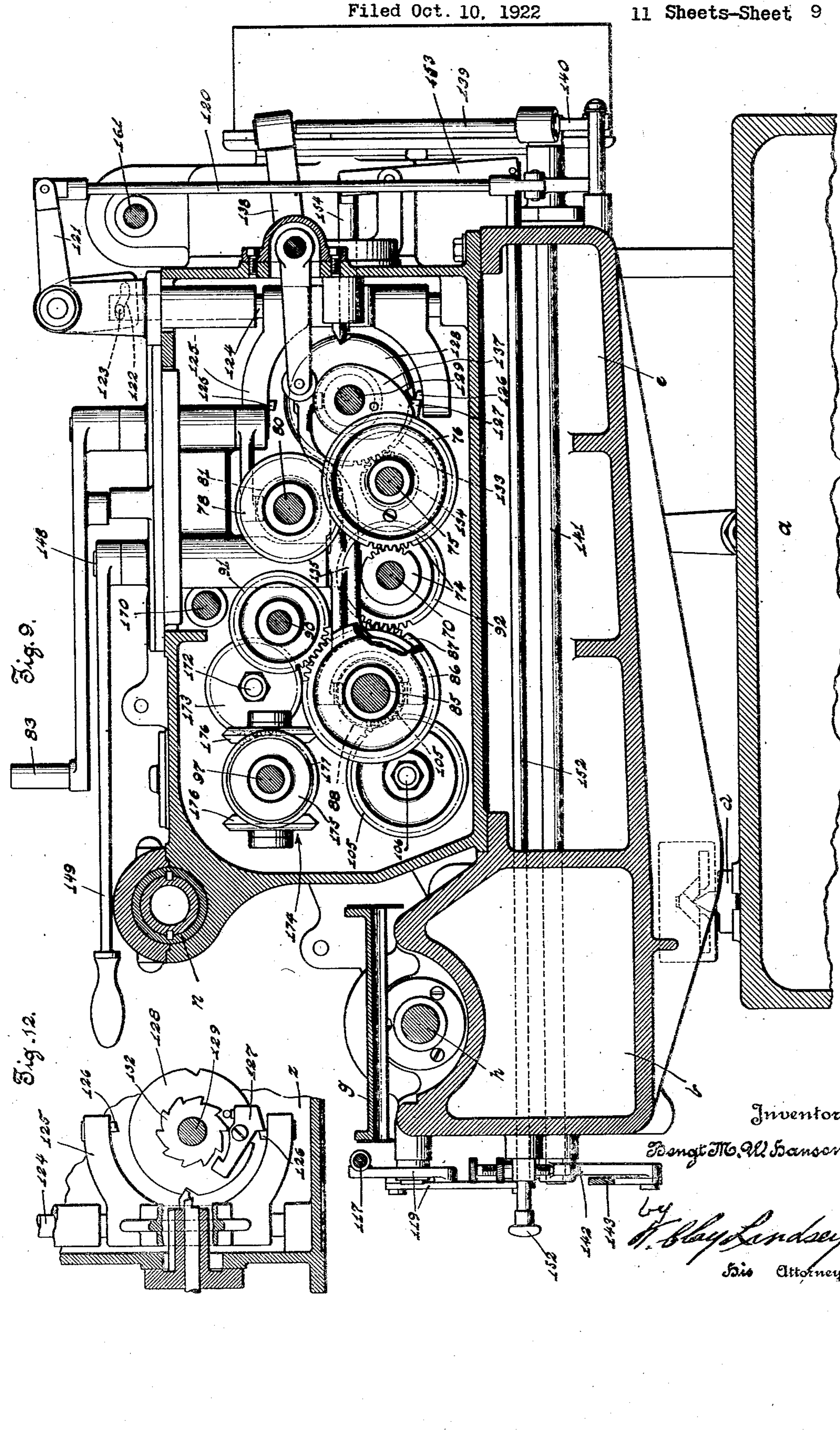

Fig. 9.

Fig. 12.

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Fig. 10.

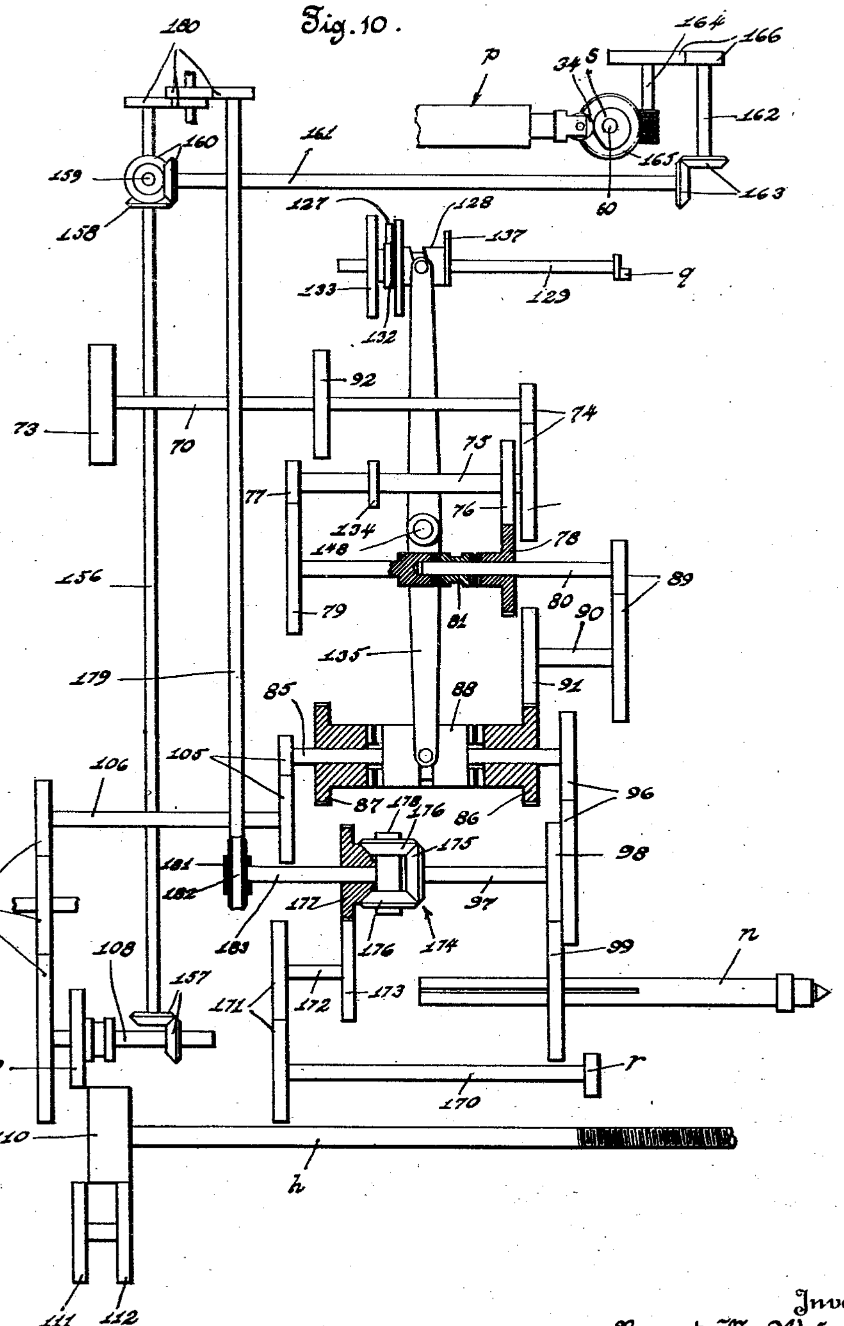


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Fig. 15.

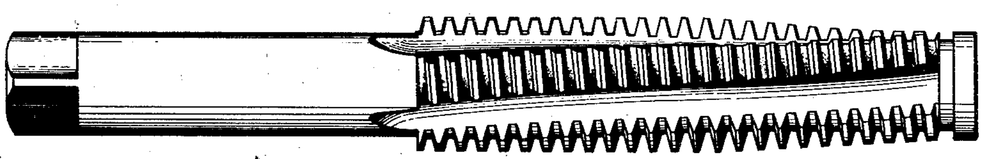


Fig. 16.

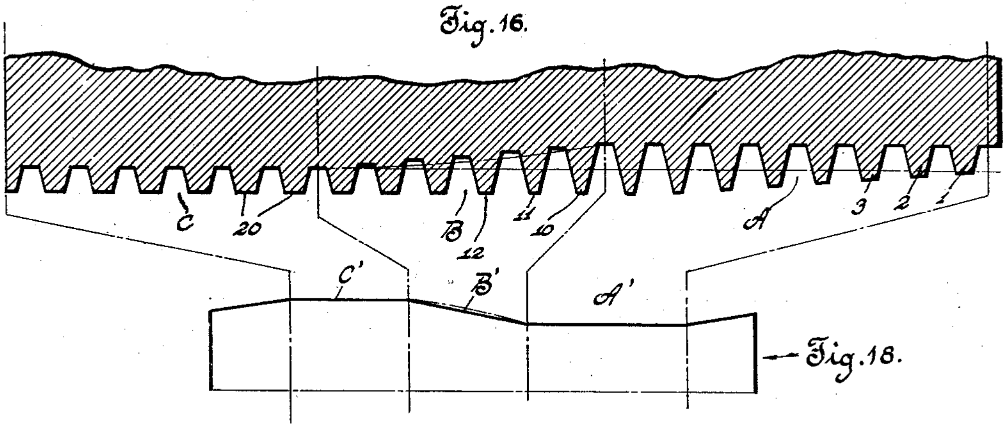



Fig. 18.

Fig. 17.

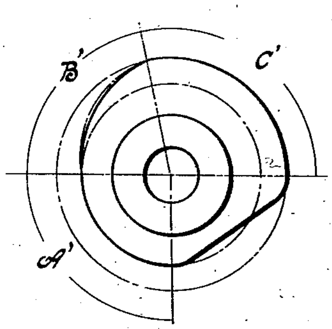
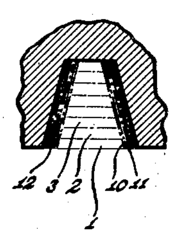



Fig. 19.

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# UNITED STATES PATENT OFFICE.

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## METAL-WORKING MACHINE.

Application filed October 10, 1922. Serial No. 593,487.

This invention relates to metal working machines of the type set forth in my copending application Serial No. 334,952 filed November 1st, 1919. In that application, I have described the machine forming the subject matter of the invention in connection with its use for shaping, contouring, or otherwise machining or finishing curved members, and more particularly with reference to the final finishing or grinding operation on a thread for the purpose of giving to that thread extreme accuracy in its shape, size and finish.

The aim of the present invention is to provide certain features of novelty and advantage in machines of this type whereby their range of usefulness and effectiveness is increased; and more particularly to provide a machine of such construction and arrangement that it may operate upon members having spiral flutes, such as spirally fluted taps, and upon members varying in diameter, such as tapered taps. These and other objects of the invention will be pointed out more in detail in the following specification.

In the accompanying drawings, wherein I have shown for illustrative purposes one embodiment which the present invention may take,

Fig. 1 is a front view of the entire machine with the grinding wheel in section;

Fig. 2 is a top plan view thereof;

Fig. 3 is the right hand end view;

Fig. 4 is a view looking at the left hand end of the upper portion of the machine with certain parts in section or broken away;

Fig. 5 is a sectional view taken vertically on substantially line 5—5 of Fig. 2 and looking in the direction of the arrows;

Fig. 6 is a detail view, showing the truing device in section;

Fig. 7 is a top view of the left hand end of the machine, the cover of the gear box being removed and certain parts being in section for the purpose of clearness;

Fig. 8 is the rear view of one end of the rocking bed, the variable connection constituting a portion of the feed mechanism for rocking the bed being shown in longitudinal vertical section;

Fig. 9 is a vertical sectional view taken substantially on line 9—9 of Fig. 7;

Fig. 10 is a diagrammatic layout showing the driving connections for the lead screw, the head stock spindle, and the several instrumentalities for rocking the rocking bed on its fulcrums;

Fig. 11 is a view in side elevation of a ratchet mechanism through which feeding of the work relative to the tool is effected;

Fig. 12 is a detailed view of an escapement ratchet clutch mechanism;

Fig. 13 is a view taken through the truing device on substantially line 13—13 of Fig. 6;

Fig. 14 is a view of a special thread;

Fig. 15 is an elevational view of one form of tap which may be finished by the use of the present machine;

Fig. 16 is an enlarged partial view thereof in section;

Fig. 17 is a cam which may be employed to obtain the desired longitudinal contour on the tap shown in Figs. 15 and 16;

Fig. 18 is a developed view of the cam shown in Fig. 17;

Fig. 19 is a view showing the manner in which the teeth on the tap cut a groove on the work.

The general arrangement and organization of the principal parts of the machine are as follows: *a* is a pedestal or fixed bed of convenient size and shape upon which is mounted a movable bed *b* carrying the work holder *c*. In the present illustrative disclosure of the invention the movable bed *b* is supported for rocking movement on fulcrums *d*, which are in the form of knife edges as most clearly shown in Figs. 1, 3, 5 and 9. The rocking bed is preferably in the form of an L, it having a longitudinally extending portion on which the work holder *c* is mounted for sliding movement and a rearwardly extending arm *e*, which carries the various instrumentalities through which the rocking bed is rocked so as to move the work relative to the tool, the latter being here shown in the form of a grinding wheel *f*. The work holder comprises a main slide or carriage *g* adapted to be moved longitudinally by a lead screw *h*, a supplemental slide *i* mounted thereon and adapted to be adjusted by turning the screw *k*, and head and tail stocks *l* and *m* respectively supported on the supplemental slide. The tail stock *m* is adjustable to accommodate pieces of work of different lengths. The head stock *l* is provided with a spindle *n*.

Pivoted on the rearwardly extending arm *e* of the rocking bed is a rocking beam *o* with which cooperates the various instrumentalities for imparting rocking movement to the rocking bed *b* and the work carried thereby. These instrumentalities, in the present instance, are four in number; being, first, mechanism, including the variable connection shown in Fig. 8 and designated generally by the letter *p*, for feeding the work to the tool when a new cut or chip is to be taken; second, means, including an intermittently rotated eccentric *q*, for moving the work from the tool during the reverse stroke of the work because backlash or lost motion in the driving connections will not permit accurate cutting of the work on its reverse stroke; third, means, including a pattern cam *r*, for rocking the bed *c* in accordance with the circumferential contour of the work operated upon, as in the case of a tap which is to be relieved back of its cutting edges; and fourth, means (which, in the present instance, includes, in part, a cam *s* resting on the top of the variable connection *p*) for swinging the work toward the tool during the cutting operation, in accordance with the longitudinal contour of the work, as in case where the piece of work varies in diameter, for instance, in the case a tapered tap is to be ground. These various instrumentalities, together with the lead screw and work spindle, are driven and controlled by the mechanism within the gear box *z* mounted on the arm *e* of the rocking bed.

Mounted on the fixed pedestal *a* rearwardly of the longitudinally extending portion of the rocking bed *b* is a slide *t* which is adjustable transversely of the axis of the head and tail stock spindles and this slide carries a bearing box *u* in which is rotatably mounted a spindle driven by the belt *x* and carrying the grinding wheel *f*. The bearing *u*, together with the grinding wheel shaft carried thereby, is angularly adjustable, as hereinafter described more in detail, to permit the grinding wheel to be brought into inclined position corresponding to the lead of the thread to be ground. The letter *v* designates generally a truing device so arranged and constructed as to give to the grinding wheel an edge corresponding exactly in size to the groove of the thread to be operated upon.

From the foregoing brief description, it will be understood that the rocking bed *b* has no movement relative to the fixed bed *a* except a rocking movement on its fulcrums comprising the knife edges *d*, and that the work holder, with the work rotatably supported between the head and tail stocks, is moved longitudinally on the rocking bed by the lead screw *h* and on a line parallel to the axis on which the rocking bed swings. The grinding wheel, during the grinding operation, is solidly fixed on the rigid pedestal *a* and the various instrumentalities above recited are on the rocking bed so as to move the work up to and away from the grinding wheel at the proper times to effect the desired shape on the work. When it is desired to true or resurface the grinding edge of the wheel, this may be done by moving the wheel into proper relation to the truing device without affecting the set or adjusted relation between the grinding wheel and the work, thus assuring, that after the grinding wheel has been trued, it may be brought again up to the work and the cutting operation proceeded with without introduction of any inaccuracies or errors.

It will be noted that the grinding wheel is solidly and rigidly supported on a fixed bed, while the work is carried by a rocking bed mounted on knife edges. This arrangement is of the utmost importance in that it assures the greatest nicety in adjustment and maximum smoothness in operation, which means that very delicate grinding operations may be carried out with accuracy and precision; vibrations, friction, and other disturbing influences being reduced to a minimum or entirely eliminated. More particularly, the grinding wheel being mounted on a relatively heavy wheel slide, and the latter being securely clamped to and rigidly held at rest on the solid bed or pedestal *a*, vibration of the wheel is practically eliminated. The grinding wheel is rotated at relatively high speeds which necessitates the use of a belt. Owing to unevenness and irregularities in the belt, it has a tendency to set up vibrations in the grinding wheel shaft, but with the present arrangement these vibrations are absorbed by the solid slide *t* and bed *a* and thus the grinding wheel is held steady and will rotate smoothly and evenly; which would not be the case were the grinding wheel mounted for movement (other than rotary) during the grinding operation. The work spindle *n* is driven at a relatively slow speed through a mechanical train of gears and therefore is not subjected to any excessive strains or stresses such as are exerted by a belt passing about a pulley. This means that the work holder may be mounted for movement on the rocking bed and the latter fulcrumed on knife edges with the result that there is little or no friction at the fulcrumed point of the rocking bed, this bed may be moved with great nicety permitting very delicate grinding operations as where a fine relief is to be had on a threaded member, and smoothness in operation and accuracy in the finished product are obtained.

Reference will now be had to the detail construction of the machine and, more particularly, to the various instrumentalities for rocking the bed on its fulcrums. The variable connection for feeding the work to the tool when a new cut is to be taken will first be described.

Referring particularly to Figs. 5 and 8, on the rear end of the arm *e* of the rocking bed is a housing 25 within which is mounted for sliding movement a nut 26 to the lower end of which is keyed a worm wheel 27 in mesh with a worm 28. In threaded engagement with the nut 26 and keyed against rotation to the housing, as at 29, is a screw 31 having a bearing at its lower end on a block 30 arising from the base *a*. Supported in the upper end of the nut 26 is a pin 33 which is preferably non-rotatable and on which the short end of the rocking lever *o* rests. The pin 33 carries, at its upper end, an anti-friction roller 34 on which the cam *s* carried by the short end of the rocking beam *o* rests. The worm 28 is carried by the shaft 35 which may be manually rotated by turning the hand wheel 36 to preliminarily adjust the work radially of the tool. This shaft is intermittently rotated (through suitable automatically operated mechanism hereinafter described) for the purpose of moving the rocking bed a slight distance toward the tool each time a new cut or chip is to be taken. It is to be understood that when the shaft 35 is rotated, the nut 26 is also rotated so that it will move up or down, as the case may be, on the screw 31 and thereby vary the distance between the anti-friction roller 34 and the block 30.

In order that the tool shall be free of the work during the reverse stroke of the latter, means which in the present instance includes the eccentric *q* is provided for raising the rocking bed away from the work on the completion of the operative stroke of the latter and moving it again toward the work when the new cut is to be taken. In the present instance, as shown most clearly in Fig. 5, the eccentric *q* is connected to the long end of the rocking beam *o* by a link 40 and an adjustable screw 41, there being a loose connection between these parts to permit of proper operation. This eccentric *q* is intermittently rotated 180° through suitable mechanism, which, as hereinafter described more in detail, includes an escapement ratchet clutch controlled by the reciprocating movement of the work holder.

For the purpose of rocking the bed together with the work thereon in such manner that the wheel will cut an irregular circumferential contour on the work, as for instance where the thread of a tap is to be relieved, the cam *r* is provided. This pattern or shaping cam acts upon (through suitable adjustable means) the long end of the rocking beam *o* (see Fig. 5). In the present instance, this cam has a single rise or lobe and is so connected up or associated with the head stock spindle and lead screw as to be driven at the proper speeds. The extent of reliefs to be made on taps will vary in accordance with circumstances. For the purpose of obtaining reliefs of various kinds or extents without going to the expense of providing a multiplicity of cams, one for each kind of relief, I provide means between the cam *r* and the rocking beam *o* for varying the action of the cam upon the rocking beam which means, of course, that the extent to which the rocking bed and the work carried thereby are rocked will be varied. As shown in Fig. 5, there is carried by and pivoted to the rocking bed, as at 43, a piece 44 carrying a roller 45 resting on the cam *r*. Journalled in the long end of the rocking beam *o* is a screw 45′ on which works a nut 46 provided with a finger 47 the lower end of which rests on the upper edge of the piece 44. The screw 45′ may be rotated in any suitable manner as by turning the hand wheel 48 which acts through the bevel gears 49. It will be understood that when the finger 47 rests on the forward end of the piece 44, as shown in Fig. 5, the rocking beam and bed *b* will be rocked by the cam *r* a minimum distance. To increase the extent to which the rocking beam is rocked, as when a greater relief is desired, the nut 46 is run back on the screw 45′ so as to move the finger 47 toward the free or rear end of the piece 44. The piece 44 is normally urged by a spring 50 in a direction to maintain the anti-friction roller 45 in engagement with the cam *r*. In order to raise the piece 44 out of engagement with the cam *r*, and thus eliminate the annoyance and jars resulting from the anti-friction roller 45 riding on this cam during the reverse stroke of the work (and during which time the finger 47 is raised out of engagement with the piece 44 by the eccentric *q*) I provide on the link 40 a projection 52 which is adapted to engage and lift an extension 53 on the piece 44 when the eccentric *q* lifts the long end of the rocking beam. It will be noted that the shaping or pattern cam *r* and the piece 44 are carried by the rocking bed, while the adjustable member or finger 47 is carried by the rocking beam *o* which in turn is pivoted on the rocking bed, thus providing a very simple arrangement which is effective in producing the desired relief on the work. The rocking beam *o* may be disassociated from the pattern cam *r* by turning down the screw 55 carried by the rocking beam, onto a stop 56 on the rocking bed to such an extent that the finger 47 is raised out of engagement with the piece 44. This is done where the piece of work is concentric and relief is not desired. As hereinafter described more in detail, the pattern cam *r* may be automatically controlled and driven in such manner that reliefs are properly effected upon spirally fluted taps, a feature which is novel and important.

For the purpose of adapting the machine for operation upon members varying in longitudinal contour, as, for instance, upon a taper tap, I provide a fourth instrumentality for swinging the bed *b* with the work thereon; this instrumentality being, in the present illustrative disclosure, the cam *s*. As shown most clearly in Figs. 4, 5, and 8, this cam rests upon the anti-friction roller 34 of the variable feed connection. The cam *s* is fixed to a shaft 60 journalled in the short end of the rocking beam *o* and driven, as hereinafter described, through suitable change gears at the desired speed depending upon the extent of longitudinal contour or taper of the work. Where the work is cylindrical, as distinguished from tapering, the taper cam *s* may not be used, and is, therefore, thrown out of operation. To this end I provide, on the shaft 60, a loose plate 62 having a high point 63 of greater radius than that of the cam *s*. Connected to this plate, as at 64, is a rod 65 which is moved longitudinally by turning the screw 66. When it is desired to disengage the cam *s* from the anti-friction roller 34 the screw 66 is turned by means of a hand wheel to a position where the high point 63 of the plate rests upon the anti-friction roller 34, as shown most clearly in Figs. 4 and 5.

The manner in which the variable feed connection *p*, the reversing eccentric *q*, the lead screw *h*, and the work spindle are driven and controlled is quite similar to that shown in my said co-pending application and will now be briefly described. As hereinafter pointed out in detail, the drive for the taper cam is connected up to the drive for the lead screw, and the pattern or relief cam *r* is driven through differential gearing associated with the lead screw and work spindle. This driving and controlling mechanism is mounted for the most part within the gear box *z* and in turn is controlled by the reciprocating movement of the work holder *c*.

The arrangement of the various shafts and gears will be readily understood upon reference to Fig. 10. Mounted within the gear box *z* is a main shaft 70 (so termed for convenience) driven by a belt 71 passing about a drive pulley 72 carried by a shaft journaled in the base *a* and also about a driven pulley 73 fixed to the main shaft. The shaft 70 drives an intermediate shaft 75 through suitable gears 74. Fixed on the shaft 75 is a pair of gears 76 and 77, which respectively mesh with gears 78 and 79 normally loose on a shaft 80. Keyed for sliding movement on this shaft 80 is a clutch sleeve 81 which is adapted to be moved, as by means of a handle 83, into clutching engagement with the gears 78 and 79 for respectively fixing the same to the shaft 80. The drive for the work spindle may be either through the gears 76, 78, or the gears 77, 79. Adjacent the shaft 80 is a clutch shaft 85 on which is a pair of normally loose gears 86, 87, which are adapted to be fixed to, so as to rotate with, the shaft 85 by means of a clutch mechanism including the slidable sleeve 88. This clutch mechanism is not shown in detail as the specific construction thereof forms no part of the present invention, it being sufficient to say that when the sleeve is moved into engagement with the clutch teeth on gear 86, this gear will be fixed to the shaft 85 and the other gear 87 will run loose, and when the sleeve is moved in the other direction the gear 87 is fixed and the gear 86 is loose. Gear 86 is continuously driven in one direction from shaft 80 through change gears 89, stub shaft 90, and gear 91. The gear 87 is continuously driven in the opposite direction by a gear 92 fixed on the main shaft 70. The work spindle *n* is driven from the shaft 85 through change gears 96, a gear 98 fixed on shaft 97, and a gear 99 meshing with the gear 98 and keyed to the work spindle *n*. The lead screw *h* is driven from the shaft 85 through the gears 105, shaft 106, change gears 107, shaft 108, and intermeshing gears 109, 110, when a right hand threaded member is to be ground. When a left hand threaded member is to be ground, the drive from the shaft 108 to the lead screw is through the gear 109, gear 111 meshing therewith, and gears 112, 110. It may be here stated that the gears 76, 78; the change gears 77, 79; and change gears 88, have been added in the present machine so as to permit the work spindle to be driven at any desired speed and to attain the selected speed in a very ready and economical manner.

The control of the driving mechanism just described is, as stated, very similar to that illustrated in my said co-pending application and operates briefly, as follows; when the work holder *c* has reached the end of its operative stroke, a dog 115 carried by this holder (see Fig. 1) engages a dog 116 on a rod 117 whereupon this rod is moved to the left and a shaft 118 is rocked through the link and lever arrangement 119 in a direction to raise a vertical rod 120 (see Figs. 8 and 9) which causes a bell crank 121 connected to the rod 120 to swing counter-clockwise, referring to Fig. 9. One arm of the crank lever is provided with a slot 122 in which engages a pin 123 carried by a rod 124 on which is mounted an escapement yoke 125. When the bell crank 121 is swung, as stated, the yoke 125, through the pin and slot connection 122, 123, is raised so that the upper stop 126 thereon is disengaged from a pawl 127 (see Figs. 7, 9 and 12) which is pivoted to a cam sleeve 128 fast on a shaft 129 carrying the eccentric *q*. The pawl 127 thereupon engages the ratchet wheel 132 which is fixed to a gear 133 normally loose on the shaft 129 and in mesh with a constantly driven gear 134 fast on the shaft 75. The pawl 127 now being in engagement with the constantly driven ratchet wheel 132, cam sleeve 128 and shaft 129 will be rotated 180° and then the lower stop 126 on the escapement yoke 125 will disengage the pawl from the ratchet wheel 132. When the cam sleeve and shaft are thus rotated 180°, the eccentric *q* will be brought into a position where the long end of the rocking beam *o* is raised, and this rocking beam now being fulcrumed on the variable feed connection *p* the work bed will be moved in a direction to carry the work out of engagement with the grinding wheel; and the cam sleeve 128 will throw a shipper lever 135 connected to clutch sleeve 88 in a direction to disengage the gear 86 and fix the reverse gear 87 to the shaft 85 whereupon the lead screw is driven in a direction to quickly move the work holder on its inoperative stroke. When the work holder has reached the end of its inoperative stroke, the dog 115 engages a second dog 136 on the rod 117 (see Fig. 1) whereupon this rod is moved to the right and through the connections described the bell crank 121 is swung in such a direction that the escapement yoke 125 is lowered thus releasing the lower stop 126 of the yoke 125 from the pawl 127 whereupon this pawl will engage the constantly driven ratchet wheel 132 and the cam sleeve 128 and shaft 129 will be rotated another 180° to effect the following: The eccentric *q* will be brought to a position where the rocking bed *b* is swung downwardly and backwardly thus moving the work towards the tool; the cam sleeve 128 will swing the shipper lever 135 in a direction to fix the clutch gear 86 to the shaft 85 and disengage the clutch gear 87 whereupon the work spindle will be driven at the proper cutting speed and the lead screw *h* will be rotated in a direction to feed the work on its operative stroke at a speed corresponding to the lead of the thread being ground. Further, a feed cam 137 fixed to the shaft 129 will rock a lever 138 (see Figs. 7, 8 and 9) which acts through a link 139, an arm 140 fixed on a rock shaft 141, the rock shaft 141, an arm 142 (see Fig. 1) fixed on the forward end of that shaft, and a link 143 to operate the ratchet mechanism shown in Fig. 11 for automatically turning the worm shaft 35 which, as stated, is associated with the variable feed connection *p*. The spring 147 (see Fig. 8) resiliently holds the lever 138 in engagement with the feed cam 137. This ratchet mechanism may be of any suitable construction, in the present instance it being conventionally shown as having a ratchet wheel 144 fixed to the shaft 35 and a lever 145 pivoted on the shaft and carrying a pivoted pawl 146 cooperating with the teeth of the ratchet wheel. When this ratchet mechanism is thus operated, the shaft 35 is turned causing the worm 28 to run the nut 26 of the variable connection *p* down the screw 31, the result being that the work is fed towards the tool to the extent that a new cut is to be taken.

The work will now be moved on its operative stroke with the grinding wheel in engagement therewith, and the sequence of operations repeated.

The shipper lever 135 is fixed to a vertical shaft 148 on the upper end of which is a handle 149 whereby movement of the work may be instantly stopped when desired, by throwing the clutch sleeve 88 into neutral position, the cam groove in the cam sleeve 128 being of increased width or offset as at 150 (see Fig. 7) so as to permit of this movement. The operator of the machine may, by merely pushing in on a rod 152 (see Fig. 9) so set the machine that the work holder will stop when it has reached the end of one of its strokes. When this rod is pushed in, it moves (through a pivoted lever 153) a slide 154 into the path of movement of the pawl 127 of the ratchet clutch mechanism. When this pawl hits the slide 154, the cam sleeve 128 will be stopped in such position that the shipper will have moved the sleeve 88 of the reverse clutch mechanism into neutral position, that is, where both of the gears 86 and 87 will be running loose on the shaft 85.

Reference will now be had to the manner in which the taper cam *s* is driven. As most clearly shown in the diagrammatic view of Fig. 10, this cam is connected up to the drive mechanism leading to the lead screw so that the cam and lead screw are driven at a predetermined ratio. Extending along the left hand end of the gear box *z* is a shaft 156 driven by shaft 108 through bevel gears 157. This shaft 156 drives, through gears 158, a vertical shaft 159 which is connected by bevel gears 160 to a shaft 161 journalled in a bearing located at the pivotal point of the rocking beam *o*. Journalled in the short end of the rocking beam *o* is a shaft 162 connected to the shaft 161 by gears 163. Also, journalled in the short end of the rocking beam *o* is a worm shaft 164 carrying a worm in mesh with a worm gear 165 on the shaft 60 on which the taper cam *s* is fixed. On the rear ends of the shaft 162 and the worm shaft 164 are change gears 166 housed within a removable casing 167. It will be noted that the drive for the taper cam extends through the axis or pivot of the rocking beam thus permitting the taper cam to be mounted on this beam and cooperate with the variable feed connection *p*. Access may be readily had to the shafts 162, 164, for the purpose of changing the gears thereon to make the taper cam rotate at the desired speed relative to the lead screw by merely detaching the removable casing or cover 167 for these gears. It will be understood, of course, that where the piece of work tapers but slightly the cam *s* will be driven at such speed that while the lead screw is moving the work the length of the tapered portion of the work, the taper cam *s* will be rotated through a small angle. Where a piece of work having a large taper is to be ground, change gears 166 of such ratio will be selected that the taper cam *s* will be driven through a large angle while the lead screw is moving the work the distance of its tapered portion. It will be seen that since the taper cam is connected up with the drive for the lead screw, it is controlled in its movement in the same manner as is the lead screw through the ratchet clutch mechanism, as above described.

The manner in which the pattern or relief cam *r* is driven will now be described. When a tap is provided with spiral flutes making spirally arranged rows or lands of teeth, the distance between the forward or cutting edges of successive teeth will be different from the distance between the cutting edges of a tap having straight flutes of the same number, that is to say, in a tap having four straight flutes there will be four teeth to each convolution of thread, but where the flutes are spiral in a direction opposite to the lead of thread there will be slightly more than four teeth to each convolution. The angular distance between the cutting edges of successive teeth of spirally fluted taps will depend, in part, on the lead of the thread and the lead of the flutes. In each convolution of the thread of a spirally fluted tap, there are a given number of teeth plus a fraction of a tooth. When a straight fluted tap, for instance, is to be ground, the shaping or pattern cam *r* (when provided with but a single rise as shown) will be driven as many times faster than the work spindles as there are reliefs to be ground, that is to say in a four fluted tap, the ratio of the cam and work spindle will be 4 to 1. In the event that a spirally fluted tap is to be ground, the drive of the relieving cam from the work spindle is modified, through differential mechanism, by the lead screw change gears 107 and by other suitable change gears which are selected in accordance with the lead of spiral flutes, so that the relieving cam is driven at a slightly greater speed than where a straight fluted tap is being ground.

Referring now to the drawings, it will be seen that the relieving cam *r* is fixed to a shaft 170 mounted within the gear box *z*. This shaft 170 is driven (through change gears 171, stub shaft 172, gears 173 and the differential mechanism indicated generally by the numeral 174) from the shaft 97, which, as previously stated, is connected up to the work spindle by gears 98, 99. This differential mechanism or speed compensating device comprises a bevel gear 175 fixed to shaft 97 and meshing with idlers 176 which turn a differential gear 177 meshing with the gear 173. When a straight fluted tap is to be ground, the shaft 179 (through which the axis of the idlers 176 is rotated) is disconnected by removing the change gear 180 on shaft 179 and securing the shaft against rotation by means of the set screw 180′ and thus the reversing cam *r* is driven solely through the mechanism which drives the work spindle *n*.

When a spirally fluted tap is to be ground, the axis or shaft 178 on which the idlers 176 of the differential mechanism are mounted is driven, as follows, from a point to the driven side of the interchangeable gears 107 which determine the rate of rotation of the lead screw. As stated, the shaft 156 is driven from a shaft 108 through the gears 157. 179 is a shaft driven from the shaft 156 through the change gears 180. On the forward end of the shaft 179 is a worm 181 meshing with a worm wheel 182 fixed on a shaft 183 on which is fixed at right angles the axis or shaft 178 of the differential mechanism. When the differential mechanism is thus driven, the rate of rotation of the relieving cam *r* is slightly increased so as to bring the speed of rotation of this cam into accordance with the disposition of the teeth on the piece of work being ground. It will be noted that the axis of the gears 178 is fixed to the inner end of the worm wheel shaft 183 which shaft is slowly rotated. Gear 177 is driven in the same direction as the rotating axis from the work spindle driving mechanism through the gears 178 which revolve about their rotating axis. Thus it will be seen that, as said axis is rotated in the same direction as gear 177, it will increase the speed imparted by the work spindle driving mechanism to said gear 177 and the cam *r*.

It will be understood that the speed at which the relieving cam is driven in case a spirally fluted tap is to be ground will depend on the following considerations: first, the speed of the work spindle; second, the lead of the thread; third, the lead of the flutes, and, fourth, the number of flutes on the piece of work. In setting up the machine, the operator will, of course, (whether the relieving cam is used or not) select the proper change gears for driving the work spindle and lead screw at the proper ratio of speed. It will be noted that the relieving cam is driven through the change gears 96, which determine the speed of rotation of the work spindle, and through the lead screw change gears 107, and thus the operator is relieved from making any calculations, adjustments or change of gears to particularly take care of the first two considerations. To take care of the third consideration, namely the lead of the spiral flutes, it is merely necessary for the operator to select the proper change gears 180 for the connection between the shafts 156, 179. The set of gears from which these change gears are selected will bear suitable indicia and may be selected without the necessity of the operator making any calculations, thus eliminating the chance of any errors and greatly facilitating the setting up of the machine. In order to take care of the fourth consideration, namely the number of flutes, the proper change gears 171 will be selected.

It is to be noted that all of the means for moving the work rotatably, longitudinally, and transversely relative to the tool or grinding wheel are connected up and driven so as to be properly co-ordinated to effect the desired contour on the work. More especially, the various instrumentalities for rocking the rocking bed have such relation one to the other and are so co-related in their operation that finished threaded members of various kinds and shapes may be very accurately and economically produced. By preference, these instrumentalities rock the bed carrying the work through the means of a rocking beam pivoted to the rocking bed, as by such arrangement these instrumentalities may operate simultaneously or in such sequence that each may properly perform its function without, where required, interfering with the functioning of another instrumentality or, where desired, modifying the operation of other instrumentalities in order to effect the desired results. This arrangement, however, is by way of preference only, it being understood that the preferred embodiment of the invention is here illustrated only for the purpose of exemplification. More particularly, it will be noted that the means for effecting a circumferential contour on the work, in the present instance, the relieving cam *r*, and the means for effecting a longitudinal contour on the work, in the present instance the cam *s*, may operate simultaneously so that relief, for example, may be effected on a thread varying in diameter, and, further, the means for modifying the rotation of the relieving cam, where the work has a spiral flute, may be employed in conjunction with the cam *s* so as to accurately and completely finish threaded members having a taper or other longitudinal contour. Also, the means for varying the throw of the relieving cam in order to thereby change the extent or depth of relief on threaded members may be used simultaneously with either or both the cams or the means for modifying the rate of rotation of the relieving cam. It will thus be seen that the machine is adapted for use in automatically grinding, for instance, threaded members having circumferential and longitudinal contours of various kinds and flutes of any desired lead. As an instance of one kind of threaded member which may be accurately ground by the use of this machine, reference may be had to the tap shown in Figs. 15 and 16. This tap is shown as having a right hand thread interrupted by left hand spiral flutes, four in number. The thread at the forward section A of the tap is tapered at its top; the thread on the middle section B is tapered at its root but cylindrical at its top; while the thread on the third section C is straight or cylindrical both at its root and top. The teeth of the first section gradually increase in height and decrease in width at their tops. The teeth of the second or middle section B gradually increase in width, while those of the third section C are uniform. The first or lowest tooth of section A (as shown in Fig. 19) will make a wide but very shallow cut as it is fed into the work; the second tooth will take a little deeper cut; the third tooth a still deeper one, and so on. Each of the teeth of section A for the most part will cut along its top but little or nothing along its sides, so that they will rough out, so to speak, a thread groove to the proper depth. The teeth of the middle section are for the purpose of cutting the groove to the proper width, each tooth taking out, as it comes into play, fine chips (as at 10, 11, etc.) out of the sides of the thread. Finally the teeth 20 of the third section will take finished cuts on the side faces and root of the thread. The extent of relief on the teeth of the several sections may be, for one reason or another, of different extents; for instance, in the case of the teeth of the middle section which, for the most part, cut on their side edges, the best results are obtained if these teeth are given a very substantial relief.

To grind, by the use of the present machine, a tap such as just described, a taper cam having a true involute or a taper cam such as shown in Fig. 17, may be employed. In either event, the selected cam is coupled up to the lead screw and thus be driven in synchronism therewith. The speed at which this cam is driven relative to the lead screw will be determined by selecting the proper change gears 166. In case a taper cam having a true involute surface, such as shown in Fig. 4, is employed, this cam will be rendered inoperative by the disk 62 while the end sections A and C of the tap are being ground and will then be thrown into operation during the grinding of the middle section B. Preferably, where a large number of taps of the same dimensions are to be ground, a taper cam corresponding to the longitudinal contour of the work will be provided and secured to the shaft. In the present instance, this cam as shown in Fig. 17, will have a concentric portion A′ corresponding to the first section of the tap, then an involute portion B′ corresponding to the middle section of the tap, and then a concentric portion C′ corresponding to the third section of the tap. In the event that the middle section B is not a straight taper, but is slightly curved longitudinally (as shown by dotted lines in Fig. 16), the portion B′ of the cam will be curved relative to the axis of the cam corresponding to the curved taper of the work. During operation of the machine on the tap shown in Figs. 15 and 16, the cam, shown in Fig. 17, will be driven in synchronism with the lead screw through the proper change gears, and the relieving cam will be driven at the proper speed in order to take care of the lead of the spiral flute of the tap by its connection with the work spindle and lead screw through the differential mechanism. The means for varying the throw of the relieving cam will be properly adjusted by turning the hand wheel. The machine will then be started and the work will be moved from end to end while in engagement with the grinding wheel. The work during its operative strokes will be moved transversely relative to the tool by the relieving and longitudinal contouring cams in such manner that the work is properly contoured circumferentially and longitudinally. The relieving cam, through its described driving connections, will be driven at such speed relative to the lead screw and work spindle that relief is effected along the spiral flutes, that is to say, the relief is spirally distributed both on the straight and tapered portions of the tap, while at the same time the taper cam is operative to effect the desired longitudinal contour on the work. The means for varying the throw of the relieving cam may be adjusted so that a greater relief, for instance, may be had on the central portion of the tap than on the end portions. This adjustment of the throw of the relieving cam may be effected without adjusting the relieving cam or taper cam or in any way disturbing the relation of these instrumentalities relative to other operative parts of the machine.

For the purpose of preventing the rocking bed *b* from being swung to such an extent that the nut 26 of the variable feed connection *n* jams against either the head of the screw 31 or the collar on the bottom end thereof, a suitable tell-tale device is provided. This device (see Fig. 8) includes a rod 184 resting on the base *a* and slidably received by a lug or bearing 185 on the rocking bed. The upper end of this rod has three marks 184′ adapted to cooperate with a line or edge 185′ on the bearing or lug 185. In setting up the machine, the operator will turn the shaft 135 until the middle mark 184′ and the edge 185′ register and then the nut 26 is in mid-position on the screw 31. When the bed is moved to such an extent that the edge 185′ approaches either of the extreme lines 184′, the operator is warned that the nut 26 is in danger of jamming against the screw 31.

The machine is provided with a work gauge by means of which the work can be very quickly adjusted with the greatest accuracy and precision relative to the grinding wheel. Because of the large size of the grinding wheel, its rough and uneven surface, and the relatively small size of the threads to be ground, it is very difficult, if not practically impossible, to accurately position the tool by merely observing its contact with respect to the work. This gauge is similar to that illustrated in my co-pending application and includes, briefly, a bracket 186 mounted for longitudinal movement axially of the work spindles in the T-slots 187 on the forward face of the rocking bed. On the upper end of this arm is a slide block 188 adapted to be adjusted longitudinally by the screw 189. Pivoted to this block, as at 190, is a gauge arm 191 carrying a pointer 192. The forward end of the pointer is shaped correspondingly to the groove of the thread to be ground. This pointer is carried by a slide 193 adapted to be adjusted radially of the work by turning the screw 194. As stated in my co-pending application, in practice to set the gauge relatively to the work, a test piece, preferably unhardened and of any diameter and having the same number of threads to the inch as the parts to be finished, is positioned between the head and tail stocks and the threads thereon are ground. Then the work gauge is thrown over into the operative position shown in Figs. 1 and 2, and the gauge is accurately adjusted to the test piece until the forward end of the pointer accurately fits into the thread. After the gauge is so adjusted, it is locked into position so that its relation to the grinding wheel will remain fixed, but it may then be thrown back into the position shown in Fig. 3 when not in use. The test piece is taken out and the piece to be finished is substituted therefor. The gauge is then thrown forward and by adjusting the slide *i* of the work holder by means of the screw *k*, the work is adjusted longitudinally until the pointer accurately fits the thread thereof. As the work is now properly set to the gauge, the operator knows that it is in correct position relative to the grinding wheel, for the gauge has already been set to the wheel by using the test piece. As the gauge is carried by the rocking bed *b* which has no rectilinear movement on the base *a* and the tool or grinding wheel is fixed to the base against movement longitudinally of the axis of the work, the relative positions of the work and gauge remain fixed. After the work is properly adjusted to the gauge, the gauge is thrown back into inoperative position and the grinding operation proceeded with.

As previously stated the bearing box *u* in which the grinding wheel spindle 196 is journalled, is angularly adjustable on the slide *t* to permit the grinding wheel to be brought into inclined position corresponding to the lead of the thread to be ground. The slide *t* (see Figs. 1, 2 and 3) is mounted on suitable ways and may be moved up to and away from the work by rotating the screw 197 having on its forward end a wheel 198 with which is associated indexing means 199 for indicating the extent of adjustment of the slide. The screw 197 passes through an opening in the rocking bed which is of sufficient size to avoid interference with the movement of this bed. In the present instance, the bearing box *u* is mounted in a way 201 (see Fig. 1) the center of curvature of which is in the center of the wheel *f* by which is meant a point at the axis of the wheel which is included in a plane bisecting the cutting edge of the wheel so that the axis about which the wheel may be angularly adjusted is on a line *a*—*b* (see Fig. 6) substantially perpendicular to the axis of rotation of the work. The drive belt *x* passes about a pulley 203 carried by a shaft journalled in the base *a* and also about a pulley 204 secured to the grinding wheel spindle 196. This belt also passes about intermediate idlers 205, 206 which are vertically and horizontally adjustable so as to permit of extreme inclination of the grinding wheel spindle. In the present instance, as shown more clearly in Fig. 3, rising from the slide *t* is a standard 207 on which is vertically adjustable, by means of a screw 208, a slide 209. Horizontally adjustable on suitable ways in this slide 209 is a second slide 210 which carries the idlers 205, 206. This slide 210 may be adjusted by a screw 211. In order to take up the slack in the belt 202, the idler 205 is carried by a bell crank 212 pivoted to the slide 210 as at 213, and urged in a direction to normally maintain the belt 202 taut by a spring 214.

The truing device *v*, by means of which the edge of the grinding wheel may be shaped in accordance with the configuration and size of the groove of the thread operated upon, is generally similar in its operation and in its relation to other parts of the machine to the truing device shown in my said co-pending application, but has certain additional features of construction which are novel and advantageous. This truing device is carried by a slide or bearing member 220 adapted to be fixed to the bed *a* by bolts 221, the heads of which engage in T-slots 222. These T-slots are parallel to the ways on which the slide for the grinding wheel is adjustable. Journalled in the bearing member 220 and adapted to be secured in any angular position of adjustment, as by a clamping bolt 223, is a pin 224 to the forward end of which is fixed a post or support 225 having a vertically disposed bearing 226, the axis of which intersects the axis of the pin 224 at right angles. The axis of the pin 224 is coincident with the line *a*—*b*, that is to say, it is in a line passing substantially through the point about which the grinding wheel is angularly adjustable and perpendicular to the axis of the work. Mounted in the bearing 226 is a hollow shaft 227 having at its lower end a projection 228 which carries a bolt or bearing member 229, the axis of which is substantially at right angles to the axis of the shaft 227 and parallel to the axis of the pin 224. Journalled on this bearing member 229 is an arm 230 in which is mounted for longitudinal adjustment the sharpening or truing tool 231 here shown as a diamond point. When the shaft 227 and the arm 230 are in the mid-position shown in Fig. 6, the diamond point lies substantially in the line *a*—*b*. The arm or tool carrying part 230 is provided with a segmental gear 232 with which meshes bevel gear 233 carried by a shaft 234 journalled in the shaft 227 and carrying an operating handle 235 at its upper end. It will be seen that by swinging the handle 235 in opposite directions the tool carrying part 230 will be oscillated through the gears 232 and 233 so as to move the diamond point or tool 231 across the face or edge of the grinding wheel being resurfaced. The shaft 227 and the parts mounted thereon which as a whole may be considered as the carriage, may be turned in the bearing 226 in order to bring the diamond point into operative relation with any face of the grinding wheel, and for the purpose of indexing it to the proper position, there is keyed to the upper end of the shaft 227, a plate 236 carrying in a suitable T-slot 236′ adjustable dogs 237 adapted to abut against the stop 238 on the post 225 For the purpose of holding the truing device in mid-position, the plate is provided with a recess 239 in which a spring pressed plunger 239′ is adapted to engage. The plate carries, on its edge, a scale 240 which cooperates with a zero mark 240′ on the stop 238 so that the dogs may be properly adjusted. The shaft 227 may be locked in any position of adjustment by turning the set screw 241. The numeral 242 designates a gauge arm carried by a pin 243 mounted in the bearing member 229. The lower end of this gauge arm carries a screw 244, the adjustment of which in the gauge arm is determined by a plurality of interchangeable gauge members in the form of flat washers or discs one of which gauge members 245 is shown interposed between the head of the screw 244 and the gauge arm. In Fig. 6, the gauge arm is shown in gauging position; during the grinding operation it is raised into inoperative position. By means of this gauge the extent of the flat or truncated portion of the grinding wheel is very accurately determined and produced. It is understood that as many gauge washers 245 will be provided as there are pitches of threads to be cut.

To set up the truing device for resurfacing the wheel, where, for instance, a U. S. standard thread is being cut (in which case the faces of the thread are at an angle of 60° and the thread is truncated) the post or support 225 will be clamped in upright or vertical position and the proper gauge member 245 will be selected for position upon the gauge arm 242. The diamond point will then be brought into engagement with the end of the screw 244. The gauge will then be thrown into inoperative position, and the dogs 237 will be so adjusted that when respectively brought into engagement with the stop 238 the diamond point is in position to resurface the side faces of the wheel at the proper (60°) angle in relation to each other. The shaft 227 will now be indexed or turned to bring one of these dogs into engagement with the stop 238 and the shaft 229 is then locked in this position by turning up the clamping screw 241. The handle 235 is oscillated to move the diamond point back and forth across the side face of the wheel with which it is in engagement. After this side face is thus resurfaced, the clamping screw 241 is loosened and the shaft 227 is turned until the other dog 237 engages the stop 238 and then the shaft is clamped in this position. The handle 235 is then oscillated to move the diamond point back and forth across the other side face of the grinding wheel. After both side faces of the grinding wheel have been retrued, the shaft 227 is turned to a position where the plunger 239′ engages in the recess 239 of the plate 236. Then the diamond point is oscillated to effect the proper truncation on the periphery of the wheel.

When, for one reason or another, it is desired to retrue the edge of the grinding wheel on a line other than that lying in a plane including the axis of the work, the post 225 may be inclined by turning the pin 224 on its axis to the desired angle and then clamping it in this position by the bolt 223. This may be desirable where the pitch of the thread is extremely coarse or where a special thread is to be ground, the angle of the sides of which is measured on the normal pitch instead of the linear pitch of the threaded member; also, where a special thread of such a shape as shown in Fig. 14 is to be ground the angle of inclination of the support or post 225 may be determined by the scale 250. This is a new feature which is of considerable value from a commercial standpoint. When the thread, such as shown in Fig. 14, is to be ground, the side faces 150 may be resurfaced with the post 225 in upright position and then the surfaces 151 retrued with the post 225 in inclined position. It is to be noted that the axis of the pin 224 lies in the line *a—b*, and the diamond point is indexible about the point of intersection of that line and the axis of the shaft 227.

It will be seen that the holder 231 for the diamond point is disposed at a slight angle in the arm 230. This arrangement is provided so that, when one portion of the diamond point is worn, by merely turning the holder on its axis a new sharp edge of this diamond point is in position to operate upon the wheel.

The truing device is in fixed relation to the work gauge after the latter has been adjusted to a piece of work and fixed in position, it being remembered that by this adjustment the work gauge is brought into fixed relation with the wheel. Consequently, these three parts, the work gauge, the wheel and the truing device, being once set for a piece of work of a given character, always remain so set with relation to one another for other work of like character.

What I claim is:—

1. In a machine of the character described, a fixed bed, a rocking bed, a grinding wheel supported on one of said beds, a slidable work holder on the other of said beds and having means for rotatably supporting a threaded piece of work, means for moving said holder in accordance with the lead of the thread on the work, and a cam operative during the cutting operation for swinging said rocking bed to effect a longitudinal contour of the work.

2. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon for rotatably supporting a piece of work, and means carried by said rocking bed and operative during the cutting operation for swinging said rocking bed to effect a longitudinal contour on the work.

3. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of

said beds, a work holder on the other of said beds for rotatably supporting a piece of work, a lead screw for moving said work holder longitudinally, a cam for swinging said bed to effect a longitudinal contour on the work, and a drive connection between said lead screw and cam including change gears.

4. In a machine of the character described, a tool holder, a work holder provided with a work spindle, a lead screw for moving one of said holders relative to the other in accordance with the pitch of the thread on the work, means coupled to said lead screw for moving one of said holders transversely of the other to effect a longitudinal contour on the work, and means coupled to said work spindle for moving one of said holders relative to the other to effect a circumferential contour on the work.

5. In a machine of the character described, a tool holder, a work holder having a spindle, a lead screw for moving one of said holders longitudinally of said spindle, a cam for moving one of said holders to effect a longitudinal contour on the work, a cam for moving one of said holders relative to the other to effect a circumferential contour on the work, and driving means to actuate said cams in timed relation to each other and to said spindle and lead screw.

6. In a machine of the character described, a fixed bed, a grinding wheel thereon, a rocking bed, a slidable work holder thereon provided with means for rotatably supporting members to be ground, a lead screw for moving said work holder, means for swinging said rocking bed to effect longitudinal contour on the work, and additional means for rocking said rocking bed.

7. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a work holder thereon, means operative during the cutting operation for swinging said bed to effect a longitudinal contour on the work, and means for intermittently rocking said bed to feed the work relative to the tool for a new cut.

8. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon, and a plurality of means for rocking said bed, one of said means resting on the other whereby it acts therethrough to rock said bed.

9. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other of said beds, feeding means for rocking said rocking bed, and means for swinging said rocking bed to effect a longitudinal contour on the work, said means resting one upon the other.

10. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon having means for rotatably supporting a piece of work, a feed connection resting on said fixed bed, and a contour cam carried by said rocking bed and resting on said connection.

11. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds having means for rotatably supporting a piece of work, means for rocking said rocking bed to effect a longitudinal contour on the work, and means for rocking said bed to effect a circumferential contour on the work.

12. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds having means for rotatably supporting a piece of work, a cam having a contour corresponding to the desired contour on the work for rocking said rocking bed to effect a longitudinal contour on the work, and means for rocking said bed to effect a circumferential contour on the work.

13. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon having means for rotatably supporting a piece of work, a lead screw for moving said work holder in accordance with the pitch of the thread on the work, means coupled to said lead screw for rocking said bed to effect a longitudinal contour on the work, and means coupled to said work spindle for rocking said bed to effect a circumferential contour on the work.

14. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon having means for rotatably supporting a piece of work, means for rocking said rocking bed for feeding the work relative to the tool, means for lifting said rocking bed during the reverse stroke of the work holder, a pattern cam for rocking said rocking bed, and means for swinging said rocking bed to effect a longitudinal contour on the work.

15. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other of said beds, a rocking beam pivoted on said rocking bed, and means associated with said beam and operative during the cutting operation for swinging said rocking bed to effect a longitudinal contour on the work.

16. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other of said beds, a lead screw for moving said work holder, a rocking beam pivoted on said rocking bed, and a cam driven in synchronism with said lead screw and associated with said rocking beam, said cam being operative during the cutting operation for swinging said bed to effect a longitudinal contour on the work.

17. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon for rotatably supporting a piece of work, a rocking beam pivoted on said rocking bed, and means carried by said rocking bed and engaging said rocking beam operative during the cutting operation for swinging said bed to effect a longitudinal contour on the work.

18. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds providing means for rotatably supporting a piece of work, a rocking beam pivoted on said rocking beds, a cam journalled on said beam, and drive connections for said cam leading through the pivotal point of said beam.

19. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds provided with means for rotatably supporting a piece of work, a lead screw for moving said holder, a cam on said rocking beam adapted to swing said bed during the cutting operation to effect a longitudinal contour on the work, and a drive connection from said lead screw to said cam through the pivotal point of said beam, said connection including change gears.

20. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder on said rocking bed provided with means for rotatably supporting a piece of work, a rocking beam pivoted on said rocking bed, feeding means for rocking said bed, and means for swinging said bed during the cutting operation to effect a longitudinal contour on the work, both of said means cooperating with said rocking beam.

21. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds provided with means for rotatably supporting a piece of work, a rocking beam pivoted on said rocking bed, a circumferential contouring cam cooperating with one end of said beam, and a longitudinal contouring cam cooperating with the other end of said beam.

22. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds and adapted to rotatably support a piece of work, a rocking beam pivoted on said rocking bed, a cam for swinging said bed during the cutting operation to effect a longitudinal contour on the work, and means for lifting said rocking bed on the reverse stroke of the work to disengage the tool and work.

23. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds adapted to rotatably support a piece of work, means for rocking said bed to feed the work towards the tool, means for lifting the rocking bed on the reverse stroke of the work, means for rocking the bed to give the desired circumferential contour to the work, and means for swinging said bed during the cutting stroke to effect a longitudinal contour on the work, all of said means cooperating with said beam to rock the bed.

24. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other of said beds, a rocking beam pivoted to one of said beds, and a plurality of means for rocking said bed, one superimposed upon another between said fixed bed and rocking beam.

25. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other of said beds, a rocking beam pivoted to said rocking bed, a variable feed connection, and a cam resting one upon the other and positioned between one end of said beam and fixed bed, and means cooperating with the other end of said beam for rocking the same.

26. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other of said beds, a rocking beam pivoted to said rocking bed, a variable feed connection resting on said fixed bed, and a cam journalled in said rocking beam and resting on said connection.

27. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder mounted for reciprocating movement on the other bed, means for moving said rocking bed to withdraw the work from the tool during the reverse stroke of the former, a cam for rocking said bed to effect a circumferential contour on the work, adjustable means for varying the throw of said cam and including a member resting on said cam, and means for raising said member from said cam when said rocking bed is moved to withdraw the work from said tool.

28. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon having means for rotatably supporting a piece of work, a rocking beam pivoted on said rocking bed, means for moving said rocking bed to withdraw the work from the tool on the reverse stroke of the work, a relieving cam journaled on said rocking bed and associated with said beam, adjustable means carried by said rocking beam and interposed between said beam and cam for varying the throw of said beam by said cam and thereby change the angle of relief, and means for lifting

said adjustable means away from said cam on the reverse stroke of the work.

29. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder theron having means for rotatably supporting the piece of work, a rocking beam pivoted on said rocking bed, means for moving said rocking bed to withdraw the work from the tool on the reverse stroke of the work, a relieving cam carried by said rocking bed, a piece pivoted on said bed and resting on said cam, a member resting on said piece and adjustable on said beam towards and away from the axis thereof to vary the extent to which said beam and bed are rocked by said cam, and an arm associated with said second mentioned means for raising said piece from said cam during the reverse stroke of the work.

30. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon adapted to rotatably support a piece of work, a rocking beam pivoted to said rocking bed, a cam cooperating with said rocking beam for rocking said bed to effect a longitudinal contour on the work, a second cam cooperating with said rocking beam for rocking said bed to effect a circumferential contour on the work, and adjustable means between said rocking beam and second mentioned cam for varying the throw of the latter.

31. In a machine of the character described, a tool holder, a work holder including a work spindle, a lead screw for moving one of said holders in the direction of the axis of said spindle, a pattern cam for moving one of said holders transversely of the other to effect relief on the work, said cam being coupled up to said lead screw and spindle through differential gearing, and speed change gears corresponding to the lead of the flute of the work interposed in the connection between said lead screw and differential gearing.

32. In a machine of the character described, a tool holder, a work holder including a work spindle, a lead screw for moving one of said holders in the direction of the axis of said spindle, a pattern cam for moving one of said holders transversely of the other to effect relief on the work, said cam being coupled up to said lead screw and spindle through differential gearing, speed change gears corresponding to the lead of the flute of the work interposed in the connection between said lead screw and differential gearing, and speed change gears corresponding to the number of flutes on the work between the differential gearing and cam.

33. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a slidable work holder on the other of said beds provided with a work spindle, a lead screw for moving said work holder, a pattern cam for rocking said bed to effect relief on the work, a drive connection between said spindle and cam whereby the same are driven in predetermined ratio and including a compensating device, and a drive connection between said lead screw and device whereby said ratio is varied.

34. In a machine of the character described, a fixed bed, a tool theron, a rocking bed, a slidable work holder thereon having a spindle, a lead screw for moving said work holder longitudinally, a rocking beam on said rocking bed, and means associated with said rocking beam for rocking said bed to effect relief along a spiral flute on the work.

35. In a machine of the character described, a tool holder, a work holder provided with a spindle, a lead screw or its equivalent for longitudinally moving said work holder, means for moving one of said holders transversely relative to the other, and driving connections between said work spindle, lead screw and means whereby the same are driven in such relation as to effect a relief along a spiral flute and on an irregular contour.

36. In a machine of the character described, a tool holder, a work holder having a spindle, a lead screw for longitudinally moving said work holder, means for moving one of said holders transversely relative to the other to effect a longitudinal contour on the work, means for moving one of said holders transversely relative to the other to effect a circumferential relief on the work, and a driving connection between said work spindle, lead screw and both of said moving means whereby the latter are driven in such relation as to effect relief along a spiral flute on an irregular longitudinal contour.

37. In a machine of the character described, a tool holder, a work holder provided with a work spindle, a lead screw for moving one of said holders relative to the other in accordance with the pitch of the thread on the work, means coupled to said lead screw for moving one of said holders transversely of the other to effect a longitudinal contour on the work, and means coupled to said lead screw and work spindle for moving one of said holders relative to the other to effect relief along a spiral flute on the work.

38. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder having a spindle on the other bed, a lead screw or its equivalent for moving said holder in accordance with the pitch of the thread on the work, and means for rocking said bed to effect relief along a spiral flute on an irregular longitudinal contour.

39. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a work holder thereon provided

with a spindle, a lead screw or its equivalent for longitudinally moving said work holder, means for rocking said rocking bed, and driving connections between said work spindle, lead screw and rocking means whereby the same are driven in such relation as to effect a relief along a spiral flute and on an irregular contour.

40. In a machine of the character described, a fixed bed, a working bed, a rocking beam on said rocking bed, a tool on one of said beds, a work holder on the other bed and having a spindle, a lead screw for longitudinally moving said work holder, means cooperating with said beam for rocking said rocking bed to effect a longitudinal contour on the work, and means associated with said beam for rocking said bed to effect a relief on a spiral flute on the work.

41. In a machine of the character described, a tool holder, a work holder for rotatably supporting a piece of work, a lead screw for moving one of said holders longitudinally of the other, means for relatively moving said holders transversely to effect a relief along a spiral flute, and means for modifying the action of said means to obtain reliefs of different extents.

42. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other bed provided with a work spindle, a lead screw for moving said work holder in accordance with the pitch of the thread on the work, a cam for rocking said rocking bed to effect a relief along a spiral flute interrupting the threads on the work, and means for varying the throw of said cam to obtain reliefs of different extents along the spiral flute.

43. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a work holder thereon provided with means for rotatably supporting a piece of work, means for longitudinally moving said holder, means for rocking said rocking bed to effect a longitudinal contour on the work, means for rocking said rocking bed to effect a relief along a spiral flute on the work, and means for varying the operation of said last mentioned means to obtain reliefs of different extents.

44. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon having a work spindle, a lead screw for moving said work holder, a rocking beam pivoted to said rocking bed, a cam cooperating with said rocking beam for rocking said bed to effect a longitudinal contour on the work, a second cam cooperating with said rocking beam, a connection between said second cam and lead screw and spindle whereby said cam is driven at such relative speed as to effect a relief along a spiral flute on the work, and adjustable means between said rocking beam and second mentioned cam for varying the throw of the latter.

45. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a slidable work holder thereon having means for rotatably supporting a piece of work, a feed connection resting on said fixed bed, a cam carried by said rocking bed and resting on said connection, and means for rendering said cam inoperative.

46. In a machine of the character described, a fixed bed, a rocking bed, a tool on one of said beds, a work holder on the other of said beds, a rocking beam pivoted to one of said rocking beds, a variable feed connection resting on said fixed bed, a longitudinal contouring cam journaled in said rocking beam and resting on said connection, and a disc carried by said beam and adapted to be turned to rest on said connection and raise said cam therefrom whereby said cam is rendered inoperative.

47. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a work holder thereon, feeding means between said rocking bed and fixed bed for rocking the former, and telltale means for indicating the angular position of said bed.

48. In a machine of the character described, a fixed bed, a tool thereon, a rocking bed, a work holder thereon, a variable feed connection between said beds, and a telltale device for indicating the angular position of said bed and including a rod resting on said fixed bed and having sliding movement in said rocking bed and cooperating indicating marks carried by said rod and rocking bed.

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