Feb. 28, 1939.

F. A. FRITZSCH

2,149,013

SPEED CHANGING MECHANISM

Filed July 22, 1937

6 Sheets-Sheet 1

Fig. 1.

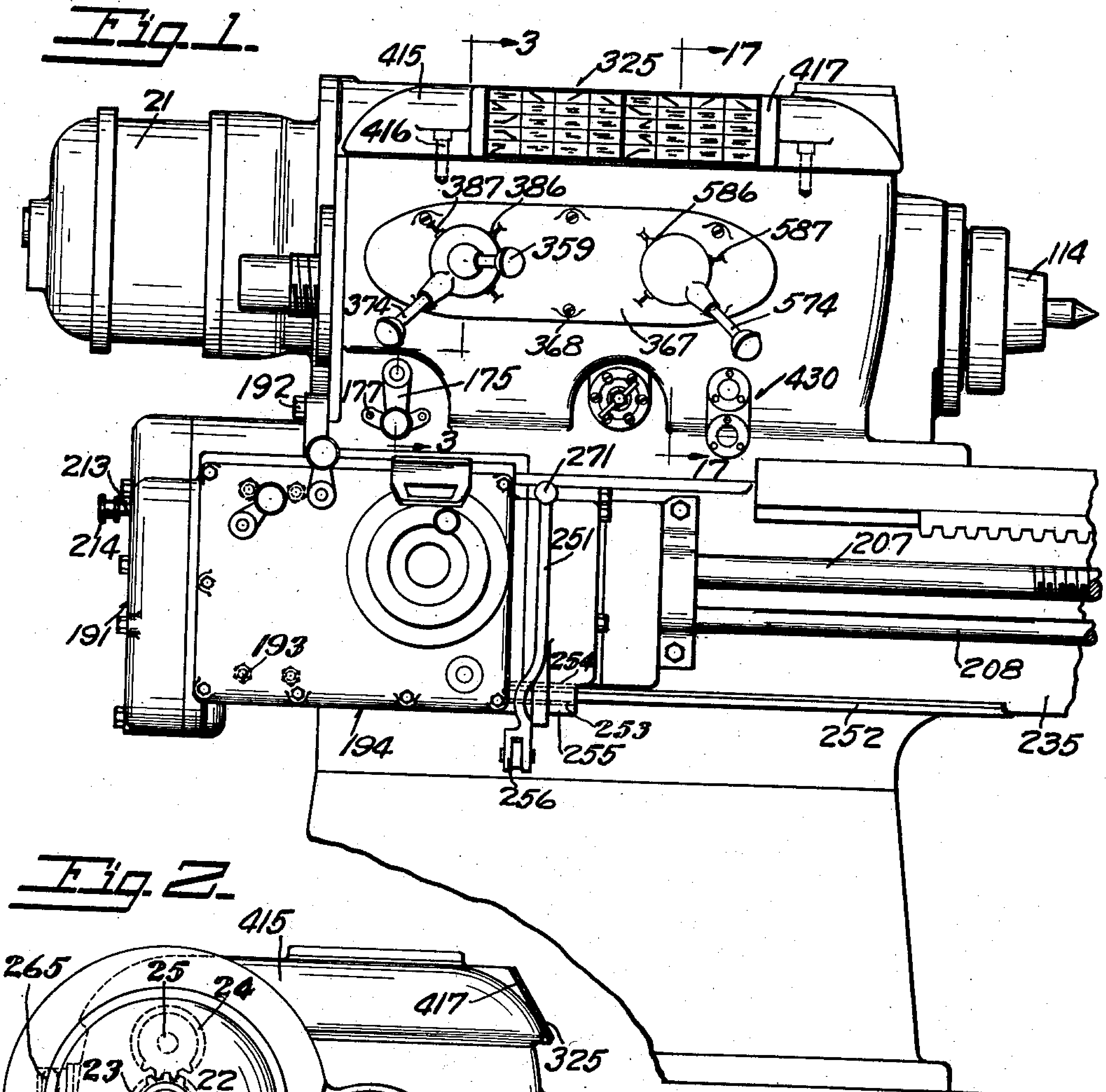
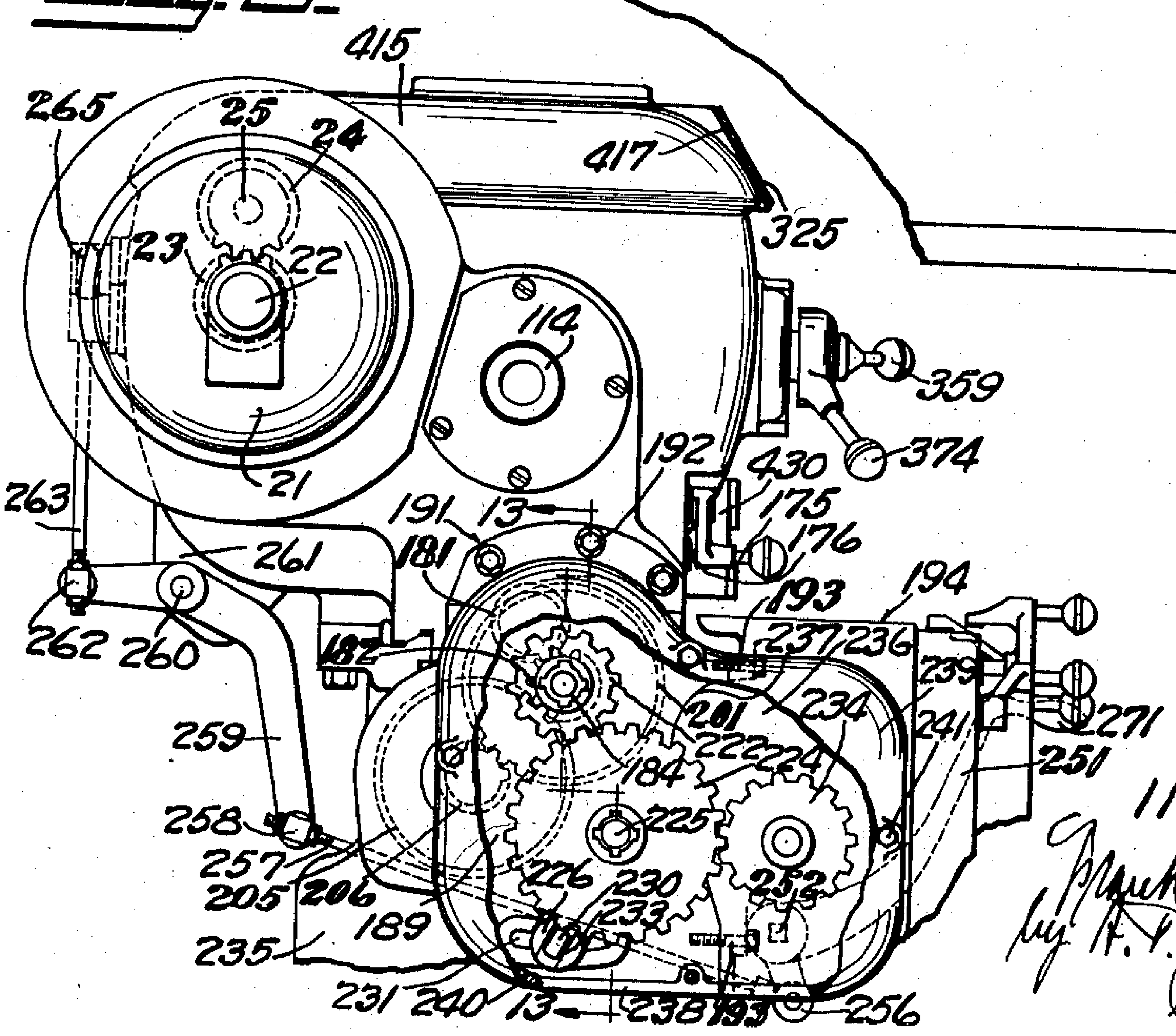


Fig. 2.



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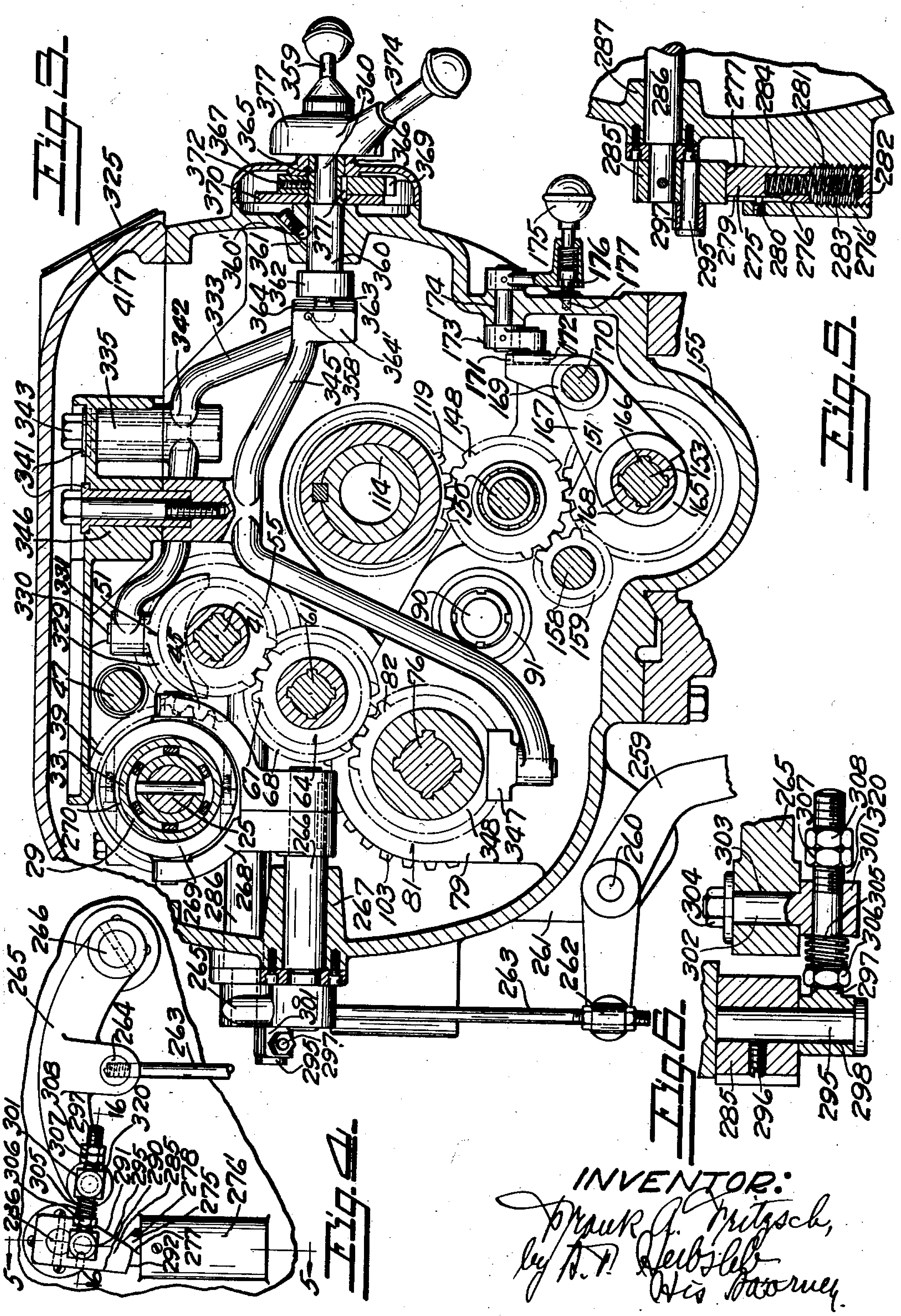
Feb. 28, 1939. F. A. FRITZSCH 2,149,013

SPEED CHANGING MECHANISM

Filed July 22, 1937 6 Sheets-Sheet 2



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Feb. 28, 1939. F. A. FRITZSCH 2,149,013

SPEED CHANGING MECHANISM

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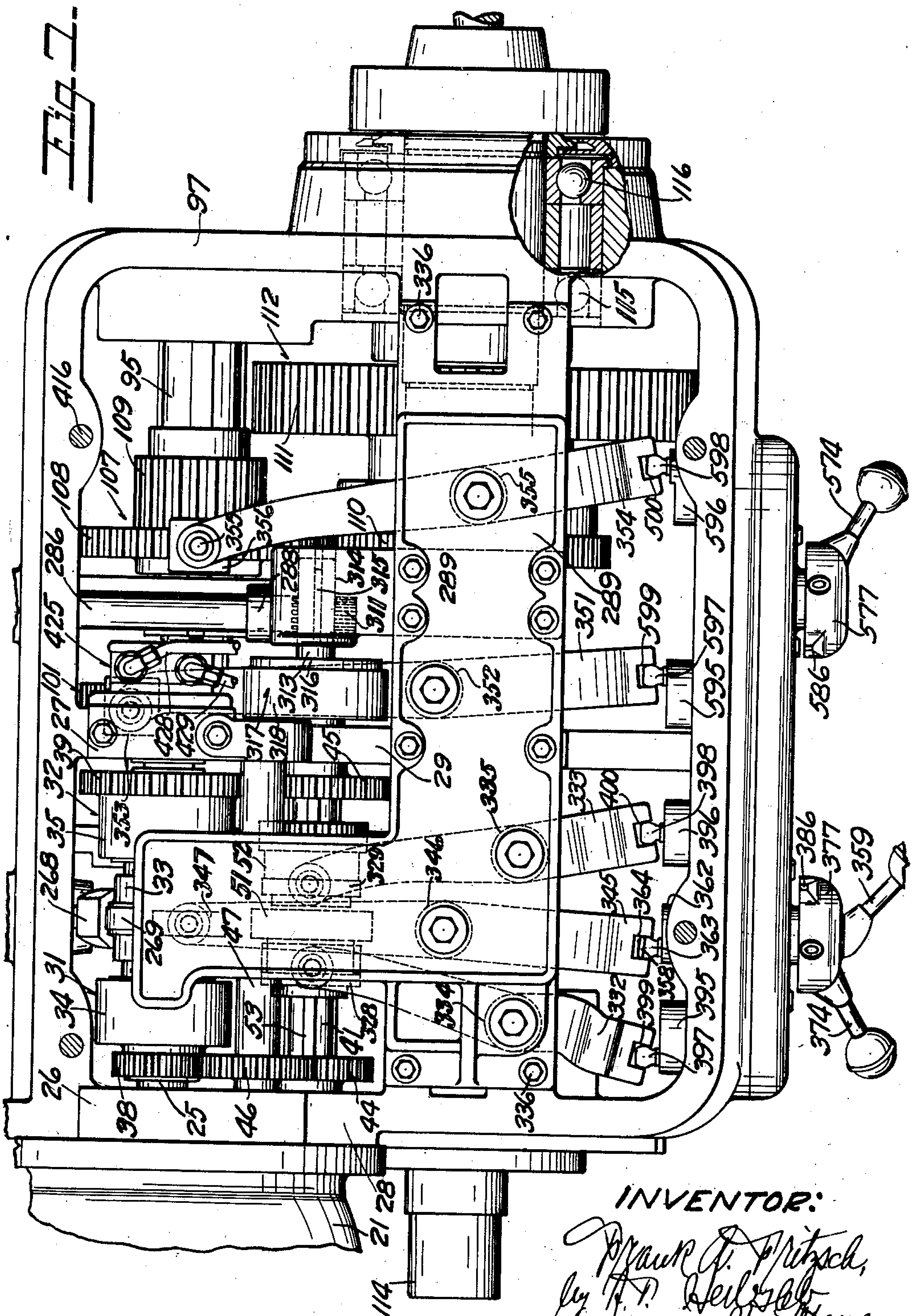
Fig. 7.



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SPEED CHANGING MECHANISM

Filed July 22, 1937 6 Sheets-Sheet 4

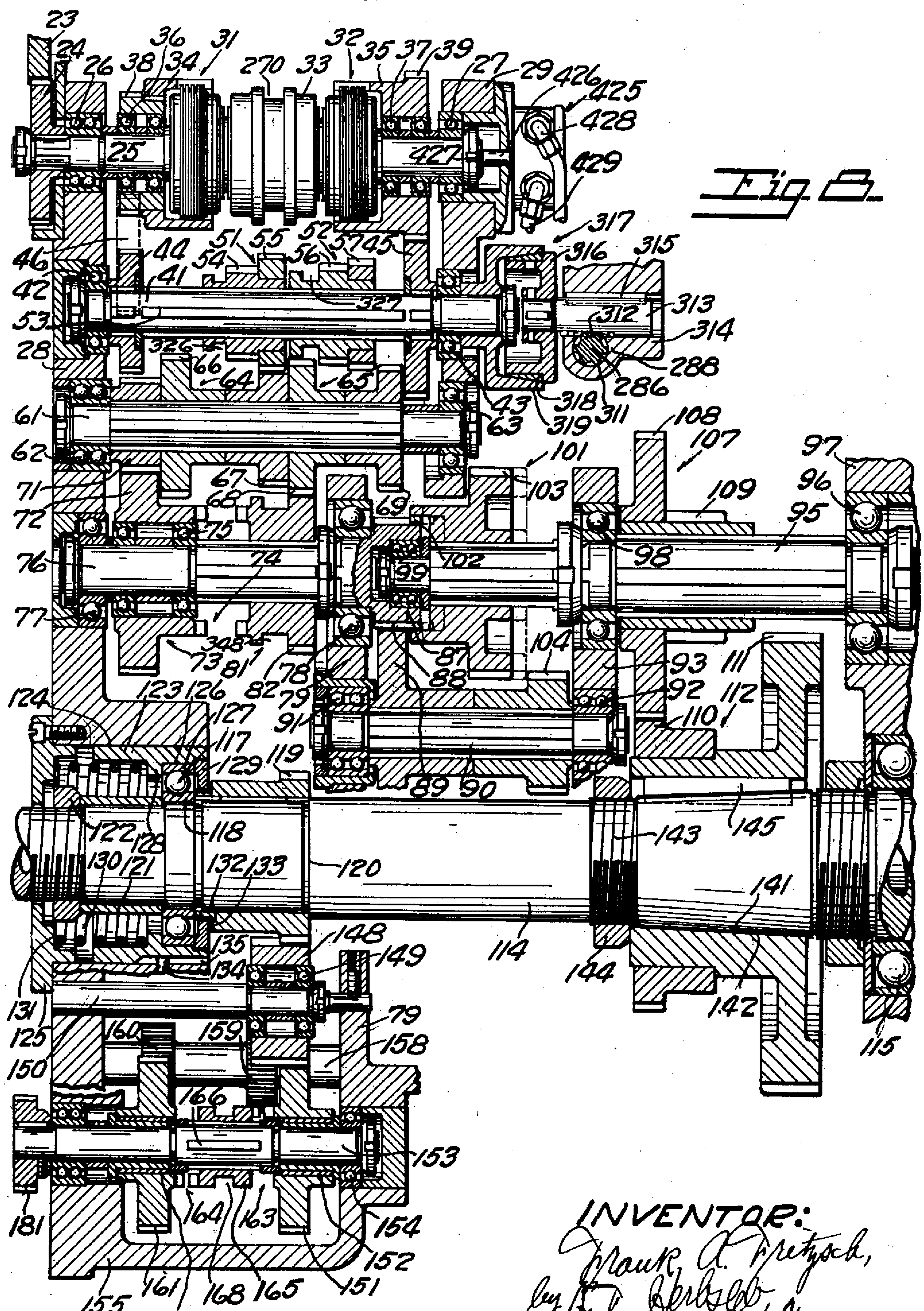

Fig. 8

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SPEED CHANGING MECHANISM

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Fig. 12.

Fig. 9.

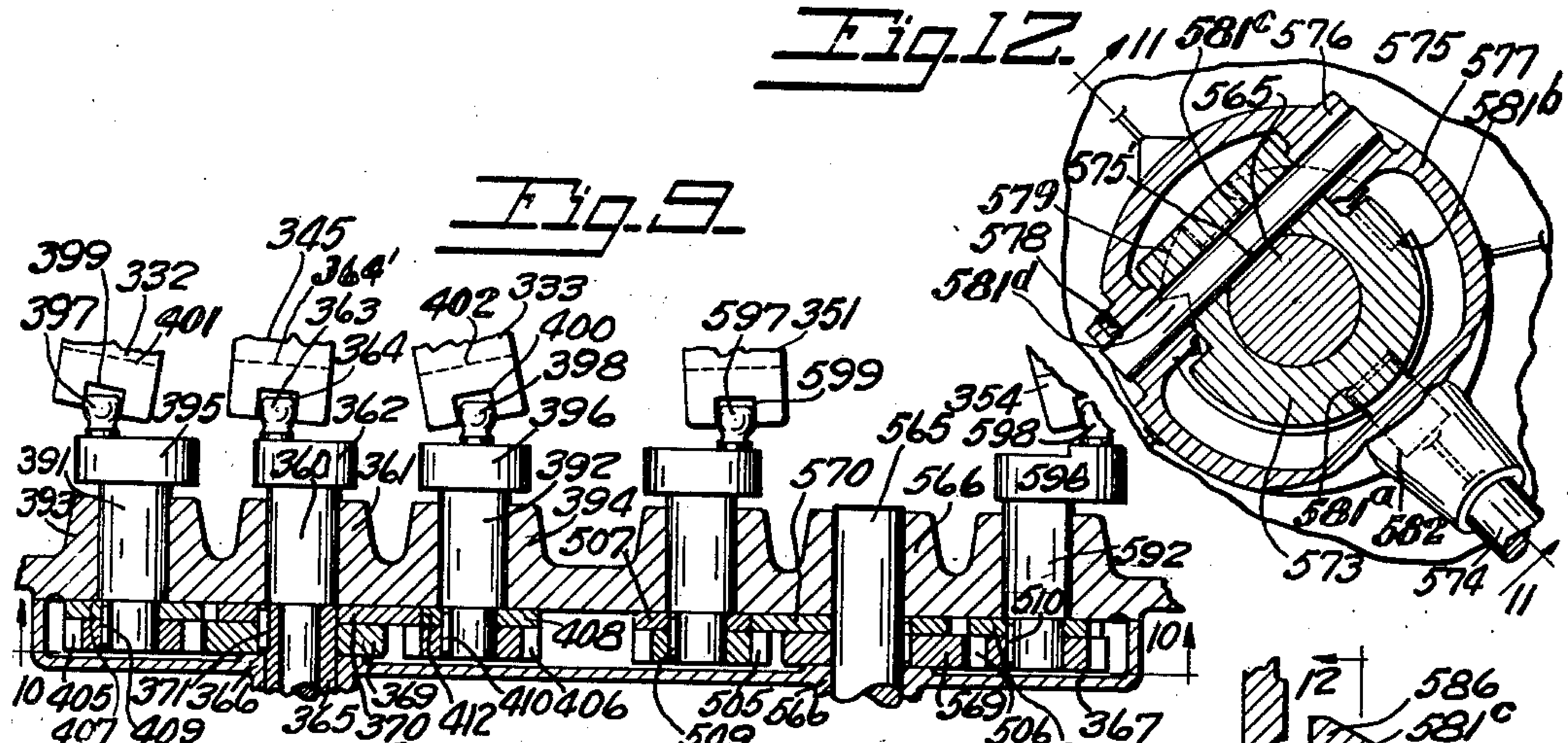


Fig. 10.

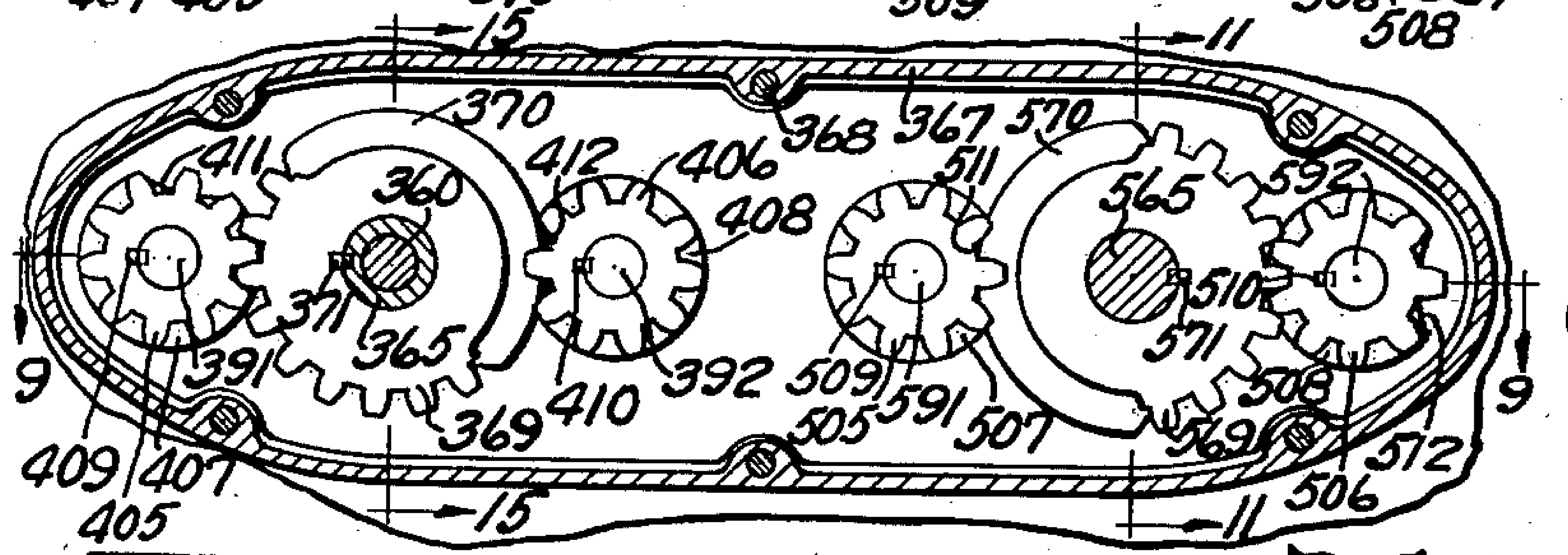
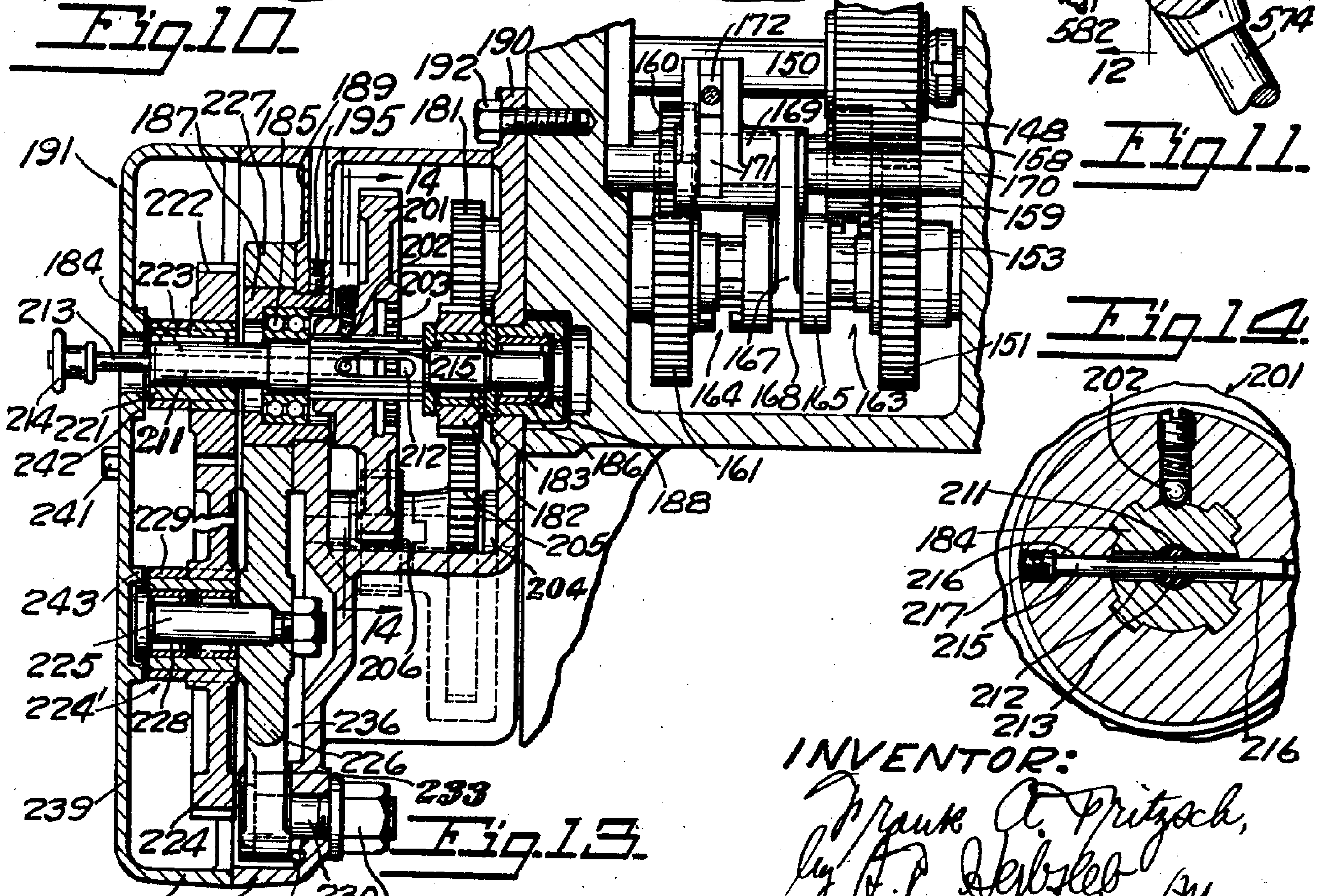


Fig. 11.

Fig. 14.

Fig. 13.



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Feb. 28, 1939. F. A. FRITZSCH 2,149,013

SPEED CHANGING MECHANISM

Filed July 22, 1937 6 Sheets-Sheet 6

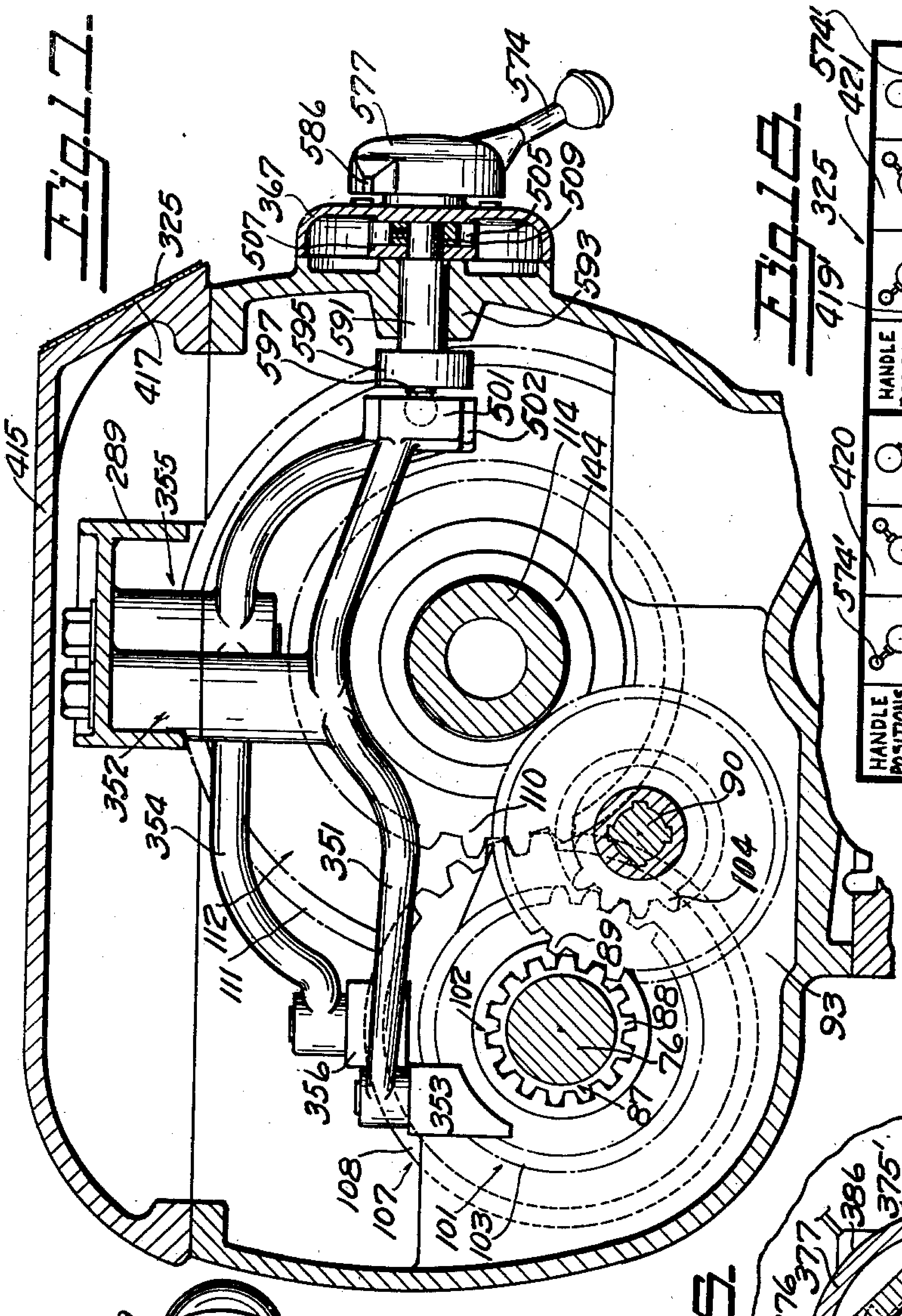

Fig. 17.

Fig. 18.

HANDLE POSITIONS				HANDLE POSITIONS			
	9	36	144		18	73	294
	11	43	173		22	88	353
	13	52	206		26	105	420
	15	61	244		31	125	500

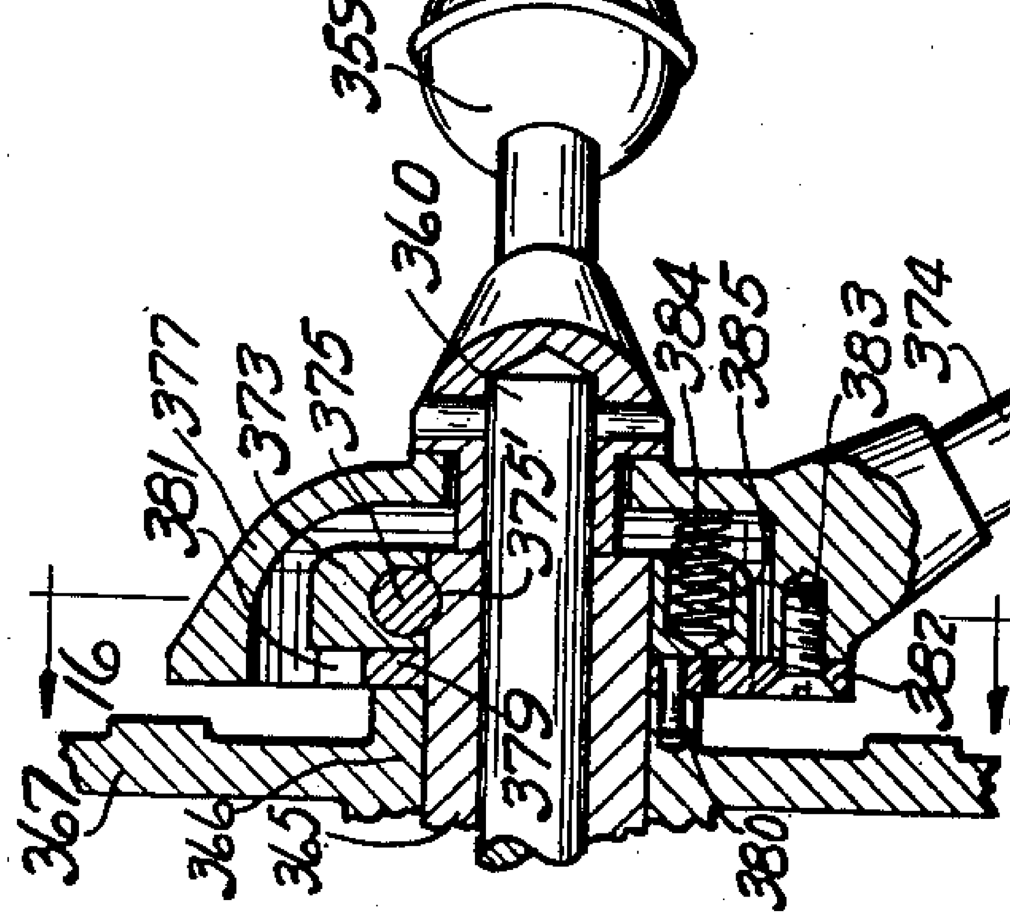

Fig. 15.

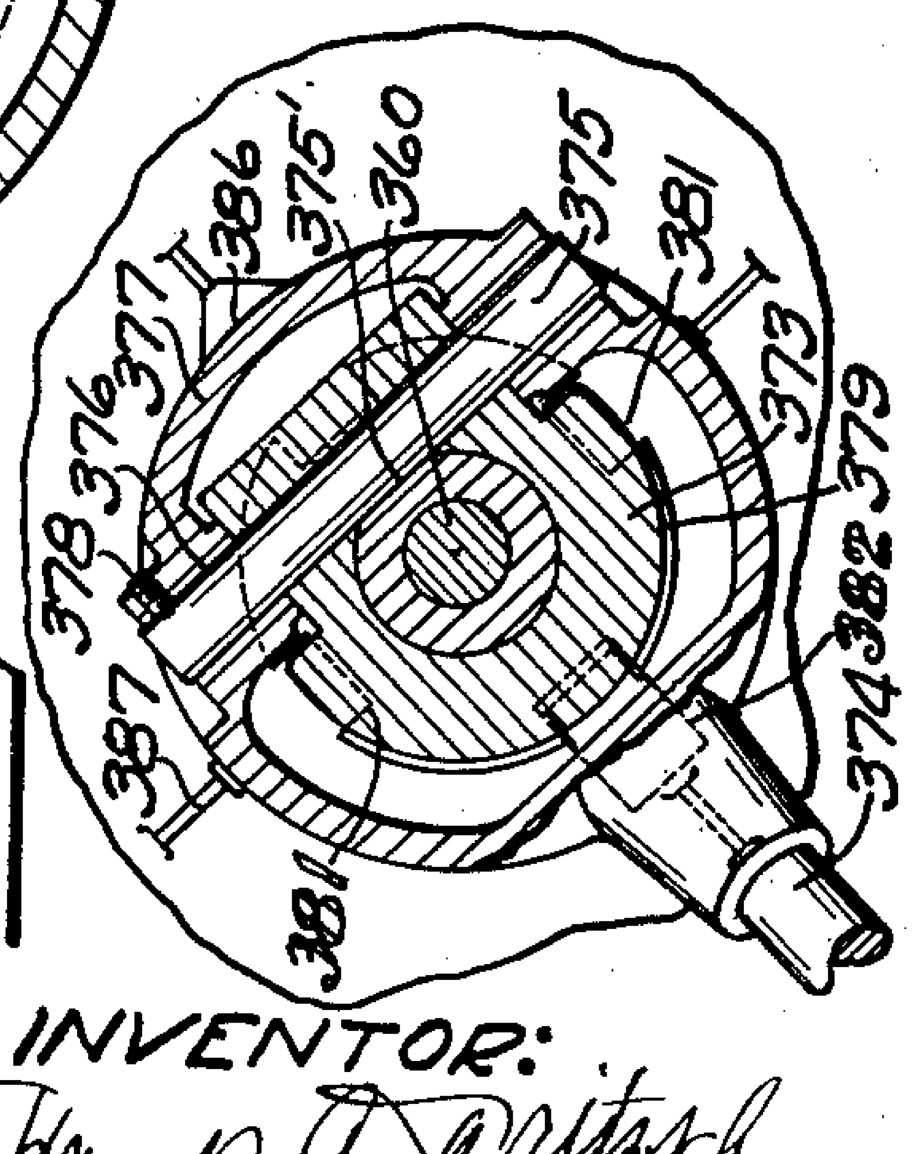

Fig. 16.

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UNITED STATES PATENT OFFICE

2,149,013

SPEED CHANGING MECHANISM

Frank A. Fritzsch, Cincinnati, Ohio, assignor to The Lodge & Shipley Machine Tool Company, Cincinnati, Ohio, a corporation of Ohio

Application July 22, 1937, Serial No. 155,072

33 Claims. (Cl. 82—29)

My invention relates to speed changing mechanism, suitable for lathes and other metal working machinery, and I have exemplified the same as applied at the head end of a lathe, for example, as located in the headstock of the lathe and in association therewith.

A desideratum in the metal turning industry has for a great many years been the removal of the excess material from the work with as great a speed as possible and with as large cuts or chips as the character of the work would permit when reducing the work to approximate form, as when roughing out the work or taking rough cuts, and also when producing the finer cuts or finishing cuts on the work.

This has led to improvements in the cutting tools, originally by hardening the steels first employed, and later by improving the steels and producing alloys of material and treating the alloys in such way as to permit of material increase of speed between the cutting tool and the work in performing the cutting operation.

It is an object of my invention to take advantage of the improvements thus provided in the cutting tools and to provide a device in which their improved properties may be best and most economically employed, and to provide an exceptionally heavy and compact speed transmission for rotating the work.

The latest improvement in tools is along the line of cemented tools and hardened alloys of various kinds. Experience has shown that some of these alloys designed for increased speed in the cutting operations are themselves brittle and inclined to rapidly deteriorate, become dull or have their cutting edges break or let down on account of inherent weaknesses or brittleness of the material of which they are composed.

It is a further object of my invention, therefore, to provide an improved speed changing mechanism whereby the speeds of operation between the work and the tool may be controlled so as to obtain the maximum life of the cutting properties of the tools combined with maximum speed of operation upon the work.

I have found, further, that it is a material advantage to let the surface speed between the work and the tool control the speeds of rotation; and it is a further object of my invention to provide novel means for accomplishing this purpose, and, further, to provide a new and improved speed changing mechanism for imparting different speeds in small steps or variations in speed, so as to provide a large number of steps of speed throughout a material range in speed and to provide such steps substantially throughout the entire range, so that a given relation of surface speed between the work and the tool may be preserved, dependent on the character of material and the resistances and brittleness of the tools which may be employed, having in mind further that the art of tool manufacture as to composition, cutting edge and other factors is progressive, to all of which my invention is peculiarly applicable in that it provides for variations in surface speed in small steps over an extremely wide range of speeds.

Exemplifying my invention as employed in a lathe in which the work is rotated by a spindle, work of this nature may be of exceedingly small diameter and also of great diameter, and may be of comparatively soft material or of very hard material, and include all the gradations of diameter and material employed in this art within the capacity of the machine, and that high speed cutting tools of various kinds may be employed in connection with all of these diameters and materials.

The diameter of the work and its speed of rotation determine the surface speed or cutting speed between the work and the tool. Given a certain piece of work composed of a given material and a cutting tool of a given kind having a predetermined cutting edge, the surface speed between the work and the tool is dependent on the resistance of the work to the cutting function and the ability of the tool to perform the cutting. Knowing these factors, the desirable surface cutting speed between the work and the tool may be ascertained, from which the speed of rotation of the work may be readily calculated.

For example, assuming that it is desired to cut a piece of work of given material by means of a tool having given properties at a given surface speed, and assuming that the piece of material is one inch in diameter, a substantially high spindle speed is obtained by my invention to produce the required surface speed between the work and the tool. Assuming, further, that with work of the same material and the same character of tool, but with the work twelve inches in diameter instead of one inch, I am enabled by my invention to obtain a spindle speed to produce the same or approximate surface speed, as in the last example, between the work and the tool by decreasing the spindle speed by means of simple mechanism, so as to reduce it to approximately one-twelfth of its speed in the first example, in order to produce the same character of action and speed of surface operation between the work and the tool.

In the first example, a spindle speed may be employed which is among the higher of the spindle speeds exemplified, and in the second example a spindle speed may be employed which is among lower ones of the spindle speeds of my improved device.

It may be assumed, further, that the tool employed in each of these instances is one of the highest developed high speed cutting tools known at the present time, or the tool employed may be one permitting less amount of cutting speed between the work and the tool. My improved device provides simple means for producing the desired speed of rotation of the spindle in any of these examples. My improved device is, therefore, very elastic throughout a wide range of work.

The same principles of operation and characters of relation between the diameters of work, cutting tools and spindle speeds may obtain in other relations, as when performing finishing cuts between the work and the tool, in which usually different characters of tools are employed for producing a desirably high finish on the work, and in which the surface speeds between the work and the tool may vary from those of the first two examples mentioned, but my invention provides means whereby the desirable surface speeds between the work and the tool translated into desirable spindle speeds may be obtained under such different relations, dependent on the relations between the work and the tool and the desired finish.

I have found that real economy in operation is provided by delicately adjusting the speed of rotation of the work, as in a lathe, to the tool of a given character, so as to preserve the cutting edge of the tool, it being understood that these cutting edges are likely to be brittle, in order that as sustained a length of uninterrupted operation between the work and the tool, translated into length of life of cutting edge of the tool, as possible is provided, for which reason it is a further object of my invention to provide a novel speed-changing mechanism in which the speeds are closely associated over a wide range, and the steps of speed are preferably in geometric progression, so that a desired speed or a close approximation thereto may be readily obtained throughout the entire range of speed.

My invention consists in novel means for accomplishing the various objects stated, and in novel means for obtaining the speeds and relations of speeds set forth; further, in a novel arrangement of gearing including shiftable elements for producing closely related speed changes over a wide range of speeds; further, in novel association of speed changing devices whereby related speed change resultants are obtained; and, further, in novel means for relating speed resultants in novel geometric progression.

My invention consists further, in novel primary, secondary, tertiary and quaternary speed changing mechanisms associated in novel manner for novel transmissions of power at different speeds; further, in novel relations of spindle driving means, in novel feeding means, and in novel mounting relation between the spindle and its gearing.

My invention consists, further, in novel means for moving the speed-changing elements; further, in novel means for controlling the same; further, in novel means for avoiding interference between the same; further, in novel visual means for positioning the controls to produce the desired relations of speed-changing members; further, in a novel index portraying relations of controls for effecting speed change in association with resultant speeds; and, further, in arranging such resultant speeds in related lines or columns and cross columns having portrayals of control handles associated therewith to portray the positions of the respective handles for producing the speeds in the respective lines or columns or at the intersections of cross columns.

My invention consists, further, in novel interlocking mechanism in the speed changing mechanism between the operating devices for effecting speed change; and, further, in novel gearing means for transmission from the spindle and novel speed-change mechanism therein, and novel means for mounting the same.

I have further exemplified my invention as employed in connection with headstock gearing in which twenty-four speeds are obtained, forward and reverse, by the employment of as little as twenty-four gears and two clutches, with the steps of speeds in regular progression in closely associated steps over a wide range and employing a geometric progression ratio preferably in a range of 1.18 to 1.20.

These ratios of geometric progression are given as examples, and illustrate the selectivity, versatility, minute steps and extreme range obtainable by my invention.

My invention will be further readily understood from the following description and claims, and from the drawings, in which latter:

Fig. 1 is a front elevation of the head end of a metal turning lathe having my invention applied thereto, and partly broken away.

Fig. 2 is an end elevation of the same, partly broken away.

Fig. 3 is a vertical section of my improved device, taken on the irregular line 3—3 of Fig. 1, and partly broken away.

Fig. 4 is a rear elevation of a detail of the same, partly broken away.

Fig. 5 is a cross-section of a detail of the same, taken on the line 5—5 of Fig. 4.

Fig. 6 is a cross-section of a detail of the same, taken on the line 6—6 of Fig. 4.

Fig. 7 is a plan view of my improved device with the cover removed, and partly broken away.

Fig. 8 is a sectional view of the gearing laid out in plane, and showing one of the power transmitting elements in neutral position in dotted lines.

Fig. 9 is a horizontal section illustrating a detail of the control mechanism, taken in the plane of the line 9—9 of Fig. 10, and partly broken away.

Fig. 10 is a vertical section of the same, taken in the plane of the line 10—10 of Fig. 9, and partly broken away.

Fig. 11 is a vertical cross-section of the same, taken in the plane of the line 11—11 of Fig. 12, and partly broken away.

Fig. 12 is a front elevation of the same, partly in section in the plane of the line 12—12 of Fig. 11, and partly broken away.

Fig. 13 is a vertical section illustrating part of the gearing, taken in the plane of the irregular line 13—13 of Fig. 2, and partly broken away.

Fig. 14 is a cross-sectional detail view of the same, taken on the line 14—14 of Fig. 13.

Fig. 15 is a vertical cross-section of a detail of the control mechanism, taken in the plane of the line 15—15 of Fig. 10, and partly broken away.

Fig. 16 is a front elevation of the same, partly in section in the plane of the line 16—16 of Fig. 15, and partly broken away.

Fig. 17 is a vertical section of my improved device, taken on the line 17—17 of Fig. 1, and partly broken away; and,

Fig. 18 is a face view of the index plate for spindle speeds.

In the present exemplification of my invention there is an electric motor 21 (Figs. 1, 2, 3, 7 and 8), the rotor of which has suitable speed imparted thereto, the rotor shaft 22 having a gear 23 fast thereon, which meshes with a gear 24 fast on a drive-shaft 25, journaled in bearings 26, 27, respectively in the head end wall 28 of the headstock and in an inner cross wall 29 in the upper part of the headstock. The drive shaft is provided with clutches 31, 32 of suitable construction, the same being shown as multiple disk clutches having a clutch operating collar 33 therebetween. The clutches are provided with suitable clutch operating levers of usual construction pivoted on a usual sleeve fixed to the drive shaft, so that upon completed movement of the clutch collar endwise in one direction one of the clutches is placed in clutching relation and upon completed endwise movement in the opposite direction the other of said clutches is placed in clutching relation, the clutch collar being normally in midposition for unclutched or neutral relation of both clutches.

Alternate disks of the respective clutches have usual spline connections with the usual sleeve rotating with the drive-shaft and the remaining disks thereof have usual spline connections with the shells 34, 35 of the respective clutches which are journaled on the drive-shaft or first shaft by friction reducing bearings 36, 37, and respectively have transmitting gears 38, 39 thereon. When either clutch is in clutched relation, the gear thereon rotates with the drive shaft and the gear on the other clutch is in idle relation with the drive shaft. When the clutch collar is in mid or neutral position between the clutches, both clutches are unclutched so that the drive shaft rotates idly in said shells.

A second shaft 41 is journaled in friction reducing bearings 42, 43, respectively in the head end wall 28 and the inner cross wall 29 of the head stock, and has gears 44, 45 keyed thereto. An intermediate gear 46 is fixed to an intermediate shaft 47, journaled in bearings in said head end wall and cross wall of the main frame, and meshes with the gear 38 and transmits motion to the reversing gear 44 keyed to the shaft 41. The gear 45 meshes with the gear 39. The gears 39 and 45 transmit forward rotation to the second shaft 41 when the clutch 32 is clutched and the gears 38, 46 and 44 transmit reverse rotation to the second shaft 41 when the clutch 31 is in clutched relation.

A pair of compound gears 51, 52 have spline connections 53 with the second shaft and are rotatable therewith and are movable axially on said shaft. The compound gear 51 includes the gears 54, 55 and the compound gears 52 includes the gears 56, 57. The gears of these compound gears are all of different pitch diameters for transmitting different speeds.

A third shaft 61 is journaled in bearings 62, 63, respectively in the head end wall and in the inner cross wall 29. It has a pair of compound gears 64, 65 keyed thereto for rotating said shaft. The compound gear 64 comprises the gears 66, 67 arranged to be respectively meshed by the gears 54, 55, and the compound gear 65 comprises the gears 68, 69, arranged to be respectively meshed by the gears 56, 57, only one of the gears of the compound gears on the second shaft being at any time arranged to mesh with one of the gears of the compound gears on the third shaft. The gears on the third shaft have different pitch diameters so as to properly receive different speeds of rotation from the gears of the compound gears on the second shaft, and form a primary speed changing mechanism.

The third shaft also has a pinion 71 keyed thereto which meshes with a gear 72 of a combined clutch and gear element 73, which latter has thereon one of the clutch faces of a clutch 74. This combined clutch and gear element is journaled by friction reducing bearings 75 about a fourth shaft 76, journaled in a friction reducing bearing 77 in the head end wall of the headstock and in a friction reducing bearing 78 in an inner bottom cross wall 79 of the headstock. This shaft also has thereon a combined clutch and gear element 81, which has thereon a mating face of the clutch 74 and comprises a gear 82. This combined clutch and gear element 81 has spline key connection with the shaft 76, so as to rotate said last-named shaft when the coacting clutch faces of the clutch 74 are in engagement, effected by endwise movement in one direction of the combined clutch and gear element 81. Endwise movement thereon in the opposite direction causes meshing of the gear 82 with the gear 68 of the compound gear 65 for transmitting rotation at a different speed to the fourth shaft when said gears are in meshing relation, forming a secondary speed changing mechanism.

A combined gear and clutch element 87 is a part of the fourth shaft 76 and comprises a gear 88 which meshes with a gear 89 keyed to a jack-shaft 90 journaled in friction reducing bearings 91, 92, the former in the inner wall 79 and the latter in the bottom cross wall 93 in the headstock.

A back-shaft 95 (Figs. 3, 7, 8 and 17) is journaled in a friction reducing bearing 96 in the tail end wall 97 of the headstock, in a friction reducing bearing 98 in the inner wall 93, and in a friction reducing bearing 99 in the clutch and gear element 87.

A combined clutch and gear element 101 has spline key connection on the back-shaft 95, and comprises clutch teeth 102 arranged to engage the teeth of the combined clutch and gear element 87, when the combined clutch and gear element 101 is moved to extreme position in one direction, shown as to the left in Fig. 8, the gear 103 thereof being arranged to be meshed with a gear 104 keyed to the jack-shaft 90 when the combined clutch and gear element 101 is moved to full extent in the opposite direction, forming a tertiary speed changing mechanism which has two legs of power, one direct to the back shaft and the other through the jack shaft.

An intermediate position of the combined clutch and gear element 101, as shown in dotted lines in Fig. 8, places both the clutch face and gear thereof in neutral or non-transmitting position.

The back-shaft has a compound gear 107 thereabout, the gears of which are on a sleeve which has spline key connection with the back-shaft so as to rotate therewith and be moved endwise thereon. This compound gear comprises gears 108, 109 fast thereon, arranged to mesh respectively with gears 110, 111 of a compound gear 112 fixed to the spindle 114 of the headstock. When this compound gear 107 is moved to full extent in one direction, as shown in Fig. 8, there is speed transmission in one ratio to the spindle from the back-shaft by meshing the gears 108, 110, and when the compound gear 107 is moved to full extent in the opposite direction, the gear 109 theerof is meshed with the gear 111 on the spindle, forming a quaternary speed changing mechanism.

The inner end of the spindle is journaled in friction reducing bearings 115, 116 in the tail end wall 97 of the headstock (Figs. 7 and 8), and in a friction reducing bearing 117 at its head end in the head end wall 28 of the headstock. Suitable means are provided for adjusting said bearings. The bearings 115, 116 hold the inner end of the spindle fixedly in endwise relation.

The bearing 117 is shown as a ball bearing and comprises an inner race 118 on the spindle. One end of this inner race bears against the outer end of the hub of a gear 119, the inner end of which bears against a shoulder 120 on the spindle. The inner end of a sleeve 121 about the reduced outer end of the spindle is clamped against the inner race by a nut 122 threaded about the outer end of the spindle. A sleeve 123 is slidable endwise in a recess 124 in the head end wall of the headstock closed by a cap 125 secured to the headstock. The last-named sleeve has a seat 126 for the outer race 127 of the bearing 117. This race is clamped in said seat between an inner flange 128 in said sleeve 123 and a closing ring 129 threaded in the inner end of the wall of said seat.

A spring 130 is located in the sleeve 123 and in an inner seat 131 in the cap 125 and bears inwardly upon the inner flange 128. The sleeve 123 is movable endwise in its bearing and is urged toward a shoulder 132 on the hub of the gear, from which it is however normally spaced by an annular space 133.

If the spindle should become heated during operation, it may expand endwise from its inner end outwardly, its inner end being held stationary endwise by its bearings 115, 116. Upon such expansion, the bearing 117, the sleeve 123, the pinion 119, and the parts about the outer end of the spindle will yield to such expansion, resisted by the spring 130, which maintains the parts about the spindle in their related positions. Rotation of the sleeve 123 is prevented by a pin 134 in the frame of the headstock located in a slot 135 extending lengthwise in the outer periphery of the sleeve 123.

The compound gear 112 about the spindle is fixed to the spindle by providing the spindle with a taper portion 141, and providing the compound gear with a taper bore 142, the spindle having a threaded portion 143 at the reduced end of the taper portion. A nut 144 is threaded about said threaded portion, and is arranged to clamp upon the inner end of said compound gear, for clamping the compound gear upon the taper of the spindle. There is furthermore a key 145 in complemental grooves respectively in the taper portion of the spindle and in said compound gear.

The spindle has the transmitting pinion 119 keyed thereto so as to rotate therewith. (Figs. 3, 8 and 13.) This pinion meshes with a pinion 148 journaled by friction reducing bearings 149 on a stationary shaft 150, the ends of which are located in the head end wall of the headstock and the inner wall 79 thereof. The pinion 148 meshes with a gear 151 journaled by a journal bushing 152 about a transmitting shaft 153 journaled by friction reducing bearings 154 in the walls of a lower extension 155 of the headstock. A reversing shaft 158 is journaled by suitable friction reducing bearings in the respective walls of said lower extension and has reversing pinions 159, 160 fixed thereon. The pinion 159 meshes with the pinion 148 and the pinion 160 meshes with a gear 161 journaled by a journal bushing 162 about the shaft 153. This rotates the gears 151, 161 in opposite directions from the spindle.

Transmission between said gears and the shaft 153 is obtained by means of clutches 163, 164 between said respective gears and a clutch collar 165, spline keyed by splines 166 to said shaft and rotating with said shaft and movable endwise thereon. The clutch collar may be placed in intermediate or neutral position so that said gears will rotate loose about said shaft in opposite directions to interrupt the power feed of the carriage of the lathe, and the clutch collar may be shifted endwise on said shaft so as to connect with either of said gears to rotate said shaft respectively in opposite directions.

The clutch may be shifted by suitable means either manually, or automatically by the carriage in usual manner, manual means for this purpose being shown as comprising a fork 167 located in an annular groove 168 in the clutch collar, the fork having a bearing 169 slidable on a rod 170 fixed in the headstock. The fork is provided with a groove 171 in which a shoe 172 is located. The shoe is pivoted to an operating crank 173 journaled in a bearing 174 in the wall of the headstock and having a handle 175, the locating pin 176 whereof is insertable in holes 177 in the wall of the headstock for locating the three positions of the clutch collar. (Figs. 1, 2, 3, 8 and 13.)

The shaft 153 has a pinion 181 fast thereon at its outer end at the outside of the headstock. (Figs. 2, 13 and 14.). The pinion 181 meshes with a pinion 182 having a friction reducing bearing 183 about a shaft 184. This shaft has friction reducing bearings 185, 186 in sleeves 187, 188 fixed in the respective walls 189, 190 of a gear box 191 fixed as by bolts 192 to the headstock and by bolts 193 to a feed box 194. The sleeve 187 is shown fixed to the gear box by a set screw 195. The shaft 184 also has a gear 201 thereabout and having spline key connection therewith. This gear rotates with the shaft and is movable endwise thereon, being positioned in its end positions by a spring-pressed ball 202, engaging notches in said shaft. The gear 201 is provided with internal teeth 203, forming a combined clutch and gear member, these teeth being arranged to engage the teeth of the pinion 182 to form a clutch between said pinion and said member.

An intermediate shaft 204 is journaled in said walls of the gear box, and has a gear 205 and a pinion 206 fast thereon, the gear being meshed by the pinion 182, and the pinion 206 being meshed by the gear 201. When these gears and pinions are in meshing relation as shown in Fig. 13, transmission is from the pinion 182 to the gear 205, simultaneously rotating the pinion 206, which meshes with the gear 201, having spline key connection with the shaft 184 for rotating said shaft at a lower speed, representing a regular feed for the usual feed screw 207 and usual feed rod 208 for feeding the usual carriage of the lathe. When the combined clutch and gear element 201, 203 is moved to the right so as to engage its clutch teeth with the teeth of the pinion 182, the transmission is direct from said pinion to said shaft at a higher speed, representing a coarse feed for the feed screw and feed rod, for example eight times the regular feed. When said clutch is in engagement, the gear 201 is out of mesh with the pinion 206, being located in the space between the pinion 206 and the gear 205, the gear 205 and the pinion 206 then rotating idly.

In order to move the combined clutch and gear element 201, 203 endwise, the shaft 184 is provided with a bore 211, with which slots 212 in the wall of said bore adjacent to said combined clutch and gear element 201, 203 communicate. A push and pull rod 213 is operable in said bore and is provided with an operating knob 214. This rod is provided with a pin 215, which is fast in the rod, and whose respective ends project radially in opposite directions through said slots and are located in holes 216 in the hub of the combined clutch and gear element 201, 203. The pin has a threaded head 217 threaded in a threaded outer end of one of the holes 216. (Figs. 13 and 14.)

The hub 221 of a change gear 222 is keyed to the shaft 184 so as to rotate therewith. The change gear has spline connection with the hub and is arranged to be slipped endwise off of the same for reception of a change gear of different pitch diameter. A collar 223 is releasable on the hub so as to hold the change gear to its hub.

The change gear 222 meshes with a change gear 224 on a stub shaft 225 fixed to a quadrant 226 having a bearing 227 about the journal sleeve 187. The change gear 224 has spline connection with its hub 224′, which has a friction reducing bearing 228 about the stub shaft 225. A collar 229 is suitably releasably located on the hub to hold the change gear 224 to its hub.

The quadrant 226 is arranged to be clamped in different radial positions by means of a bolt 230 in said quadrant passing through an arcuate slot 231 in the wall 189 of the gear box, and clamped in adjusted positions by means of a nut 232 threaded over said bolt. The head of the bolt is shown flat sided and located in a slot 233 of the quadrant to prevent turning of the bolt.

The change gear 224 is arranged to be placed in proper meshing relation with a gear 234. This gear is the initial gear for the speed changing system in the feed box 194 secured in suitable manner to the bed 235 of the lathe for controlling the speeds of rotation of the feed screw and the feed rod for the carriage. The outer end of the gear box 191 and the outer end of the feed box 194 are provided with a cavity 236 which extends across the joint 237 between said gear box and said feed box, and has therein the quadrant and the gears thereon and the gears with which said latter gears mesh, the cavity being provided with a marginal flange 238. A cover 239 covers said cavity, and is provided with an oppositely inwardly extending flange 240, which forms a joint with said first-named outwardly extending flange, bolts 241 passing through holes in said cover and threaded into lugs extending inwardly from the flange 238 to hold the cover in place. The cover is provided with inwardly extending flanges 242, 243 to hold the change gears 222, 224 and their hubs in place.

The means for operating the clutch collar 33 comprise an operating lever 251 (Figs. 1, 2, 3, 4, 5 and 6), secured to a square shaft 252 in a journal bushing 253 journaled in a bearing 254 in a lug 255 on the feed box. This shaft extends lengthwise of the bed to the carriage where it may be provided with a similar operating lever. The operating lever 251 is articulated at 256 with a link 257 which has an adjustable articulation 258 with a lever 259 pivoted on a stud 260 fixed in a lug 261 extending from the headstock. The latter lever has an adjustable articulation 262 with one end of the link 263, the other end of the link being pivoted by a pivot 264 to an operating arm 265 fixed to a rock shaft 266 journaled in a bearing 267 in the headstock and having keyed thereon an operating fork 268 provided with pivoted connected shoes 269 located in the annular groove 270 of the clutch collar 33. Either clutch is engaged by endwise movement of the clutch collar, accomplished by operation of the operating handle 271 of the operating lever 251 by moving the handle upwardly about the pivot of the operating lever for engagement of one of the clutches and moving the handle downwardly for engagement of the opposite clutch.

A spring-pressed plunger 275 is movable up and down in a bore 276 in a bracket 276′ of the headstock and has oppositely tapered engaging faces 277, 278. The plunger has a slot 279 in which the end of a positioning screw 280 threaded into the wall of the bore is received. One end of the bore is threaded at 281 for having a plug 282 threaded into one end of the bore, a spring 283 having one end seated in said plug and the other end thereof received in a socket 284 in the plunger and engaging the end of the socket, the spring operating to force the plunger outwardly.

A control arm 285 is fixed to a rock-shaft 286, journaled in a bearing 287 in the rear wall of the headstock, and in a bearing 288 bracketed from a bridge 289 mounted in the headstock (Fig. 7). The control arm has opposite contact faces 290, 291 arranged to coact with the opposite contact faces of the plunger 275, and has an arcuate riding face 292 between said faces, the curve of which is described from the center of the rock-shaft 286. A headed pivot pin 295 is fixed in the control arm by a set screw 296. A link 297 has an eye 298 about the pivot pin between its head and the control arm. This link passes through a pivoted block 301, having a shank 302 extending therefrom in the form of a shoulder bolt pivoted in a bearing 303 of the arm 265 and held rockingly in place by a nut 304 threaded over the threaded reduced end of said shank. A spring 305 encircles the link 297 between said block and a nut 306 threaded on said link for adjusting the tension of the spring. At the other side of the block an adjusting nut 307 and jam nut 308 are threaded on said link to adjust the moment of operation of the control arm by means of the operating lever 251.

The link 297 and that portion of the control arm 285 between the pivot pin 295 thereon and its rock shaft 286 form link extensions of the operating arm 265, or toggle links, which are arranged to be extended or collapsed to operate the rock shaft 286.

The rock shaft 286 has a pinion 311 thereon, (Figs. 7 and 8), which meshes with a rack 312 on an endwise movable stem 313 slidable lengthwise in a stationary bearing 314 of the headstock adjacent to the bearing 288. This stem is prevented from turning by a key 315 located in opposite grooves in said stem and said bearing. The stem has the brake member 316 of a brake 317 fixed thereon, this brake member being provided with a tapered brake lining 318 received in the cup member 319 of said brake, secured to the end of the second shaft 41 of the headstock gearing.

The operating means for this brake are so arranged that the brake is moved into engaged relation, so as to cause cessation of rotation of the gearing, as the clutch collar **33** is moved into neutral position, and so as to move the brake into release relation when the clutch collar **33** is moved into clutching relation for clutching of either of said clutches for either forward or reverse rotation of the headstock gearing.

The parts (Figs. 1, 2, 3, 4, 5, 6 and 8) are shown in normal relation for clutch release and brake engagement. When the operating handle **271** is moved in either direction, the operating arm **265** is either raised or depressed. When the parts are in normal relation the axes of the rock-shaft **266**, the pivot block **301** and the pivot pin **295** are in a straight line. Movement of the operating arm **265** out of normal position either up or down moves the pivot block up or down out of such line so as to place said arm and the connecting link **297** into angular relation, thereby decreasing the right line distance between the axes of the rock shaft **266** and the pivot pin **295**, and swinging the control arm **285** and rocking the rock shaft **286** to operate the brake.

There is normally a slight space **320** between the pivot block **301** and the adjusting nut **307**, permitting a desired idle movement between the operating arm **265** and the link **297** to permit an initial movement of the clutch collar **33**, preparatory to effecting a transmissive engagement in the driving clutches, without affecting the brake. As soon, however, as the block **301** acts upon the adjusting nut **307** to move the same, the link **297** is moved endwise and swung on its pivot **295** for moving the control arm **285** and releasing the brake and also depressing the plunger **275**, and placing the intermediate face **292** on said control arm opposite the apex of the plunger for permitting the end of the control arm to ride upon the plunger while the control arm is moved to further extent by the operating handle to place the opposite face **290** of said control arm into line with the opposite taper face **278** of said plunger, the plunger then moving outwardly for resiliently forcing further movement of the control arm and holding the control arm in its moved relation, whereby clutch engagement and brake release are assured.

This relation of control parts is obtained when operating the operating handle **271** in either direction for engagement in either clutch for forward or for reverse rotation of the spindle. When the operating handle is operated for release of the clutches, the control arm is again moved to the other side of the plunger and the brake is applied just in advance of release of the clutch.

The spring **305** avoids chatter of the parts and it also aids in supplementing the spring **283** to hold the brake in engaged relation, and the free space **320** permits full operation of the plunger for such engaged relation in the brake and for taking up wear in the parts.

In the speed changing mechanism four speeds are imparted to the third shaft **61** by endwise shifting of the respective compound gears on the second shaft **41** (Fig. 8). These four speeds are multiplied by two by the endwise shifting of the compound clutch and gear element **81**, to engage the clutch **74**, or to mesh the gears **82**, **68**, for imparting eight speeds to the fourth shaft **76**.

These eight speeds may be transmitted direct to the back-shaft **95** by engagement of the clutch **102**, in which relation the jack-shaft **90** and the gears thereon rotate idle. These eight speeds may be multiplied by two by shifting the compound clutch and gear element **101** for meshing of the gears **103** and **104**, in which relation the transmission to the back-shaft is through the gears **88** **89**, **104** and **103**, resulting in sixteen speeds in the back-shaft. Sixteen speeds may thereby be transmitted to the spindle when the gear **108** of the compound gear **107** is in mesh with the gear **110** about the spindle, and sixteen additional speeds may be transmitted to the spindle by shifting the compound gear **107** for meshing of the gear **109** thereof with the gear **111** fixed to the spindle, transmitting thirty-two speeds to the spindle.

In practice, however, in the present exemplification, the gears **88**, **89**, **104** and **103** have practically a one to four ratio in transmitting from the fourth shaft to the back-shaft, the transmission from the back-shaft to the spindle through the gears **108**, **110**, which have a one to one ratio, resulting in a given speed of the spindle.

This spindle speed, with the gear ratios as exemplified, is substantially the same in its various steps as the speed imparted to the spindle when the clutch **102** is in clutched relation for rotating the back-shaft at the speed of the fourth shaft and the gears **109**, **111** are in meshing relation, the latter being at substantially a one to four ratio.

I have therefore provided control mechanism by which such duplication is avoided. By means of this control mechanism clutching relation in the clutch **102** with selective gear relation between the compound gear on the back-shaft and the spindle gears is employed, and the transmission through the meshing gears **88**, **89**, **104**, **103** to the back-shaft plus the meshing of the gears **108**, **110** is eliminated resulting in twenty-four different speeds.

The full thirty-two different speeds may, however, be obtained by changing the one to four ratio in either of the trains recited, and further spindle speeds may be obtained by adding additional pairs of mating gears having different pitch diameters between shafts, or the number of spindle speeds may be decreased by eliminating selective transmission pairs. The ultimate speeds obtained may also be multiplied by employing a multi-speed motor for the initial drive.

I have provided shifting and control means for arranging the transmission elements for imparting twenty-four different speeds to the spindle, and the gear and clutch ratios are such in my improved device that the spindle speeds are arranged in substantial geometric progression from the lowest to the highest, employing a ratio factor in a range of substantially 1.18 to 1.20, the ratio factor employed in the present exemplification being approximately 1.19, that is to say, each higher speed substantially equals the next lower speed multiplied by 1.19. The resultant speeds are shown on an index plate **325** in Fig. 18, fractions in the products being disregarded. It is to be understood, however, that my invention includes any arrangement of clutch and gear elements approximating that herein shown and described, and equivalents thereof, within the scope of the appended claims, and regardless of the ratio or factor employed in obtaining resultants, or whether or not any such ratio factor be employed.

The means for changing the positions of the speed change elements and of locking the same in changed relations, where advisable, are exemplified as including a series of levers, one of the ends of which have connections with the speed change elements for moving the latter, and the other of the ends of which are operated by suitable handles some of which are locked in moved positions.

Thus the compound gears 51, 52 (Figs. 3, 7, and 8), are respectively provided with annular grooves 326, 327 in which shoes 328, 329 are respectively received. Each of these shoes has a trunnion 330 rockable in a bearing 331. These shoes are respectively at the swinging ends of levers 332, 333 respectively pivoted in bearings 334, 335 in the bridge 289, the respective ends of which respectively have support on the end walls of the headstock, being clamped in place by bolts 336. Each of these pivotal connections comprises a headed bushing 341 located in its bearing and supported by its head on the bearing, the bushing extending below the inner end of said bearing. The lever has a recess 342, in which the lower end of the bushing is located. A bolt 343 is located in said bushing, the head end of the bolt being supported on the head end of the bushing, and the threaded end of the bolt being threaded into the end wall of the recess 342 in the lever for clamping the lever, the bushing and the bolt together endwise, and allowing the bushing to be rocked in its bearing when the lever is operated to shift the compound gear.

A lever 345 has a similar pivotal connection in a bearing 346 in the bridge, the swinging end of said lever being provided with a pivoted shoe 347. The shoe is located in an annular groove 348 in the combined clutch and gear element 81 for shifting the latter endwise.

A lever 351 has similar pivotal connection 352 with the bridge, the swinging end of said lever being provided with a pivoted fork 353 received about the outer periphery of the gear 103 of the combined gear and clutch element 101 for shifting the latter axially for engagement either in the clutch 102 or meshing of the gear 103 with the gear 104. The fork has pivotal connection with the swinging end of said lever similar to the pivotal connection between the shoes and the levers 332, 333 and 345.

A lever 354 (Figs. 7 and 17) has pivotal connection 355 with the bridge, this pivotal connection being similar to the pivotal connection between the lever 332 and said bridge. The lever 354 is provided with a fork 356 at its swinging end received about the outer periphery of the gear 108 of the compound gear 107. This fork has pivotal connection similar to the pivotal connection between the fork 353 and its lever 351.

A series of handles is provided for operating said levers. (Figs. 1, 2, 3, 9, 10, 15 and 16.) Thus there is a handle 359 which is fixed to a crank-shaft 360, journaled in a bearing 361 in the front wall of the headstock and having a crank 362 at its inner end provided with a crank pin 363 which is located in a slot 364 of an enlargement 364' of the front end of the lever 345. The relation of the parts is such that the handle may be shifted to project laterally and horizontally in either direction so that either the clutch 74 or the gear 82 of the combined clutch and gear element 81 is in power transmission relation, and when in such relation the crank pin 363 and the axis of the crank-shaft 360 are in a plane perpendicular to the pivotal axis of the lever 345, thereby placing said parts on dead centers, and thereby holding the parts in shifted relations, with the combined clutch and gear element at its endwise limits of movement, the resistance to rotation of the rock-shaft being sufficient to hold the parts in such actuated locked positions aided by a spring-pressed ball 360' resiliently received in sockets at opposite sides of said crank-shaft. A pin 358 across the slot 364 above the crank pin 363 compels shifting of the handle 359 in an upward arc.

There is a hollow shaft or sleeve 365 (Figs. 3, 9, 10, 15 and 16) about the reduced end of the crank-shaft 360. The sleeve 365 is journaled in a bearing 366 of a cover 367, secured to the front wall of the headstock by screws 368 for enclosing the gearing and lock plates, to be presently described. This sleeve has a segment gear 369 secured thereto, a lock plate 370 being also secured to said sleeve, as by means of a key 371 and a set-screw 372. A hub 373 of an operating handle 374 is fixed to said sleeve, as by means of a pivot pin 375 in a notch 375' in said sleeve and located in bearings 376 at its respective ends in a shell 377 at the inner end of said handle, and fixed in said bearings by a set screw 378 (Fig 16).

This handle and shell are pivoted by said pivot pin for coaction with a locating disk 379 fixed to the bearing 366 by means of pins 380 and provided with notches 381 in which a lug 382 secured to the inner end of the shell by a screw 383 is arranged to be received to hold the segment gear 369 and lock plate 370 in moved positions.

Four of these notches are shown complementary to the four positions in which the compound gears 51, 52 are arranged to be placed on the second shaft 41 for selective meshing with the gears on the third shaft 76. The positioning lug is normally urged into latching relation with its respective slots by a spring 384, one end of which is received in a recess 385 of the hub 373, its other end bearing upon the outer wall of the shell. The shell is provided with a pointer 386 arranged to register with suitable marks 387 on the cover about the axis of the sleeve 365, to indicate the respective positions of the handle for clutch and gear engagement effected by the handle.

Crank shafts 391, 392 are journaled respectively in bearings 393, 394 in the front wall of the headstock and at their inner ends are provided with cranks 395, 396, provided with crank pins 397, 398 respectively operable in slots 399, 400 of enlargements 401, 402 at the forward ends of the levers 332, 333 respectively. The outer ends of these crankshafts are respectively provided with pinions 405, 406 and with lock plates 407, 408, the respective pinions and lock plates being rotatively secured to the crank shaft by keys 409, 410. The teeth of the segment gear are arranged to be brought into mesh selectively with the teeth of the pinions 405, 406 for selectively rotating the cranks 395, 396. These teeth are shown extending throughout substantially one-half of the pitch circle of the segment 369, and are arranged to impart a substantially complete rotation to the respective pinions 405, 406, the balance of said segment gear being recessed inwardly beyond the meshing circle of its teeth and throughout such portion being free of tooth engagement with said respective pinions. That portion of the lock plate 370 which is located in the angle extended of the free portion of the segment is extended outwardly radially to substantially the circle extended of the teeth of the segment, the balance of said lock plate being recessed inwardly beyond said tooth circle.

The respective lock plates 407, 408 rotating with the respective crank-shafts 391, 393, are respectively provided with arcuate recesses 411, 412, extending throughout given angles of said respective lock plates 407, 408, into which the extended portion of the intermediate lock plate 370 is received when the teeth of the segment pass the teeth of the pinions on said respective crank-shafts for holding said respective crank-shafts in operated positions until reengagement of the teeth of the segment with said respective pinions by selective positioning of the handle 374.

These angular recesses are so located that when the extended portion of the lock plate 370 is located in the angular recess of one of the lock plates 407, 408, the crank pin of the crank-shaft to which said latter lock plate is secured is in an intermediate position, for placing the compound gear on the second shaft with which it is connected, in neutral position, as shown by the right-hand compound gear 52 and the crank pin 398, respectively in Figs. 8, 9 and 10.

When either of these crank pins and the axis of its crank-shaft are in a single plane perpendicular to the axis of the pivot of the lever operated thereby, either to the right or to the left of the axis of rotation of the crank, then one of the gears of the compound gears on the second shaft is in meshing relation with its coacting gear, the parts being so constructed and arranged, however, that only one of said gears can be placed in meshing relation at any given time, during which also the other compound gear on said shaft is in neutral position.

There is a similar arrangement for operating the levers 351, 354 (Figs. 7, 9, 10, 11, 12 and 17), except that the intermediate crank-shaft 360, its handle 359 and the operative parts connected therewith are omitted, the parts being indicated by similar reference numerals raised to the series 500. In this example the hollow shaft or sleeve 365 has a shaft 565 substituted therefor, this shaft being journaled in a bearing 566 in the front wall of the headstock. The crank pins 597, 598 are arranged to be moved into positions located in a plane perpendicular to the pivotal axes of the levers 351, 354, in which plane the axes of their crank shafts 591, 592 are located, at opposite sides of said respective axes.

Such positions of the crank pin 597 position the combined clutch and gear element 101 either in clutch engagement or in gear engagement at the respective ends of its movements, and such positions of the crank pin 598 position the compound gear 107 either for meshing of the gears 108, 110, or for meshing of the gears 109, 111.

The pair of handles 359, 374 and the handle 574 are located in separated relation at the front of the headstock. (Figs. 1, 3, 7 and 17.) These handles may be rotated in either direction for obtaining different transmitting relations of the shiftable speed changing elements.

A cover 415 is provided for the headstock and is secured thereto by bolts 416. The cover is provided with a front angular face 417, which slants downwardly and forwardly and is presented toward the line of vision of the operator while simultaneously viewing the handles, so that the positions of the handles may be changed in connection with the observation of an index plate 325 secured to said face. Said index plate has vertical columns 418, 419 in which the power transmission positions of the levers or handles 359, 374 are portrayed at 359′, 374′, respectively at the head ends of horizontal lines or columns 418′, 419′ of numerals stating spindle speeds, and with a horizontal line or column or columns 420, 421 in which the power transmitting positions of the lever or handle 574 are portrayed at 574′, respectively at the head ends of vertical columns 420′, 421′ of numerals stating spindle speeds.

These lines or columns 418′, 419′, 420′, 421′ form cross-columns, at the intersections of which the spindle speed is shown which corresponds to the connections obtained in the speed changing mechanism by the placement of the handles in the positions portrayed at the head ends of said crossing columns. The train of power transmitting mechanism as shown in the drawings is represented as in relation for transmitting the highest speed to the spindle, namely, 500 revolutions per minute, as shown in the space at the intersection of the last of the cross columns 419′, 421′.

A suitable lubricant pump 425 (Figs. 7 and 8) has its casing secured to the inner wall 29 of the headstock and has an operating shaft 426, which has operative connection 427 with the drive shaft 25. A feed pipe 428 leads to said pump from a suitable sump formed by the bottom portion of the frame of the headstock and a discharge pipe 429 leads from said pump and distributes lubricant to the respective gears and bearings of the headstock and gearing herein shown and described. The height of the lubricant in the sump may be observed through a suitable window 430.

In the operation of my invention, as exemplified, a desired angular relation between the segment gear 369 and its pinions 405, 406, and the lock plate 370 and its coacting lock plates 407, 408, is shown in Figs. 9 and 10, such relation being caused by positioning the handle 374 droopingly to the left as shown in Figs. 1, 2, 3, 7, 15 and 16, and as portrayed at the bottom of column 419 in Fig. 18. The meshing relation of the segment gear 369 with the pinion 405 shows shifting connection with the compound gear 51, and the locking relation of the lock plate 370 with the lock plate 408 shows locking of the compound gear 52 in idle relation.

When the segment gear leaves one of its pinions, the compound gear connected therewith has been placed in idle relation and the lock plate 370 simultaneously enters the angular recess in the lock plate rotating with said pinion to lock said compound gear in such idle relation until the segment gear again meshes with its pinion, whereupon the other compound gear is locked in idle position. When the teeth of the segment gear leave one of the pinions, the crank pin actuated by that pinion is in the same vertical plane in which the axis of its crank shaft is located, and has placed the compound gear with which it connects in idle position.

Referring to Figs. 1, 3, 7, 8, 9, 10, 15 and 18, the handle 359 is rotated into a position to extend to the right of its axis, as pictured in the fourth space of column 419, in which position its crank pin 363 is at the left of the axis of its crank shaft, for swinging the lever 345 to mesh the gear of the combined clutch and gear element 81 in the secondary speed changing mechanism.

Referring to Figs. 1, 7, 8, 9, 10, 11, 12 and 17, the crank pin 597 is in position for clutch engagement of the combined clutch and gear element 101 and the crank pin 598 is in position for meshing of the gear 108 with the gear 110 for highest spindle speed, the handle 574 being droopingly positioned to the right as shown in Fig. 1 and portrayed in the last space in column 421 in Fig. 18. With this relation of the parts, the segment gear **569** is in midmeshed relation with the pinion **506**, and the lock plate **570** is in midlocked relation with the lock plate **507**, so that when the segment gear leaves either of its meshing pinions, the crank pins operated thereby respectively are in position for power transmission of the elements shifted thereby. In the relation of the parts stated, the lug **582** on the handle **574** is in a notch **581***a* of the locating disk **579**.

If the handle **574** be moved counter-clockwise ninety degrees, the lug **582** being placed in the notch **581***b* (Fig. 12), the pinion **505** will remain stationary, being in locked condition by its lock plate, for maintenance of clutch engagement of the combined clutch and gear element **101**, and the pinion **506** will have been rotated one-half revolution, resulting in shifting of the compound gear **107** for meshing of the gear **109** with the gear **111**, this position of the handle being portrayed in the second space of the column **421** in Fig. 18, for transmitting ultimate spindle speeds shown in the column therebelow in the present exemplification by different transmitting relations in the primary and secondary speed changing mechanisms.

A further rotation of the handle **574** counter-clockwise ninety degrees, into the position portrayed in the first space in column **421** (Fig. 18), places the lug **582** into the notch **581***c* (Fig. 12), rotates the pinion **505** one-half revolution, placing the crank pin **597** at the left of the axis of its crank shaft and thereby shifting the combined clutch and gear element **101** for meshing of its gear **103** with the gear **104**, the compound gear **107** remaining locked by the lock plates **570**, **508** with its gear **109** meshed with the gear **111**.

Twenty-four different speeds are thus transmitted to the spindle.

A further rotation of the handle **574** counter-clockwise throughout an angle of sixty-two degrees, places the lug **582** in the notch **581***d*, and rotates the pinion **505** and the crank pin **597** accordingly, and thereby shifts the combined clutch and gear element **101** into idle relation between the gears **88**, **89** and the gear **104**, as shown in dotted lines in Fig. 8, to disconnect the spindle from the primary, secondary and the major part of the tertiary speed changing mechanisms. This permits ready manual rotation of the spindle independent of the major portion of its driving train, as when adjusting work with relation to the spindle or on a face plate which may be attached to the spindle so as to rotate therewith, when fastening the work, and for other desirable setting up and adjusting purposes, or for attention to the parts.

The fourth ninety degree angular position of the handle **574** is eliminated, as note the absence of a notch opposite the notch **581***b* in the locating disk **579** in Fig. 12.

By skipping this fourth ninety degree angular position of the handle **574**, the simultaneous meshing relation of the gears **103**, **104** and **108**, **110** is avoided in the translations of the clutch and gear element **101** and the compound gear **107**, as such simultaneous meshing relations would result in a speed change of one to four in the tertiary and quaternary speed changing mechanisms, which is the same as the speed change obtained by engagement in the clutch of the combined clutch and gear element **101** and meshing relation of the gears **109**, **111**, induced by the second position of the handle **574** above described in which its lug **582** is placed in the notch **581***b*, as portrayed in the second space of the column **421** in Fig. 18.

My improved device presents a gear transmission which is powerful, and which provides for a wide range of speeds divided into small steps to produce a great number of speeds with a comparatively small number of speed transmission elements, the steps in the present exemplification being in geometric progression from the lowest to the highest speed and employing a factor in a range of substantially 1.18 to 1.20, preferably approximately 1.19, the fractions in the products being disregarded.

The index in Fig. 18 discloses that speeds from nine to five hundred revolutions per minute are obtained in twenty-four steps, as an example, providing great flexibility by my improved device.

If rotation of the spindle at a given speed, say 206 R. P. M. is desired, the numeral **206** is found on the index in Fig. 18, shown in the third space of each of the columns **418′**, **420′**. The positions of the handles **359**, **374** portrayed in the third space of the column **418**, and the position of the handle **574** portrayed in the third space in the third column **420**, in said index, show the directions in which said handles are to be placed on the machine to obtain the positions of speed changing elements for producing the spindle speed of 206 R. P. M. desired.

The arrangement of the transmitting mechanism into primary, secondary, tertiary and quaternary speed changing mechanisms sequentially arranged and employed throughout the speed range, permits the use of simple and powerful shiftable speed change elements and simple shifting means for the same operable by simple handle manipulations readily observed, and placed according to the portrayals of said handles on a chart or index on which the selective spindle speeds are shown columnwise and cross-columnwise in relation to the handles.

Selective ones of these handles shift a plurality of shiftable speed change elements, locking selective ones of such elements in shifted relation to avoid interference between elements, and insuring that transmissions by the shiftable elements shall all be in sequence to produce the selected spindle speed.

Instancing the flexibility, convenience and economy in operation of my improved device, if an operator is rough cutting a piece of work by employment of any of the speeds shown in the columns **418′**, **420′**, and he has finished the rough cutting and desires to finish cut the piece of work, all he needs to do is to shift the one handle **359**, shifting it from the left to the right of its axis, as compare the portrayals of said handle at **359′** in columns **418** and **419**, thereby substantially doubling the speed for finish cutting the piece of work, as compare the speed at any intersection of the columns **418′**, **420′** with the speed at a corresponding intersection of the columns **419′**, **421′**, in Fig. 18.

My improved device provides for economic mounting of the parts and for various speeds of the carriage feeding parts and reversals of the same by simple speed changing devices which are strong, compact and readily shifted.

It is obvious that changes in the preferred embodiment of my invention herein shown and described and in the various parts thereof and their relations may be made within the spirit of my invention as stated in the following claims.

I claim:

1. In gearing of the character described, the combination of a driving means, a driven member, primary speed changing mechanism, secondary speed changing mechanism, tertiary speed changing mechanism and quaternary speed changing mechanism serially arranged between said driving means and said driven member and transmitting power in the same direction through all said speed changing mechanisms for all speeds in the same direction of said driven member, two of said speed changing mechanisms transmitting duplicate series of speeds, and control means neutralizing transmission of one of said duplicate series of speeds in one of said speed changing mechanisms while maintaining such transmission of the other of said series of speeds to nullify such duplication of speeds, and constructed and arranged whereby substantial geometric progression of speeds throughout all said speed changing mechanisms is maintained.

2. In gearing of the character described, the combination of a driving means, a driven member, primary speed changing mechanism, secondary speed changing mechanism, tertiary speed changing mechanism and quaternary speed changing mechanism serially arranged between said driving means and said driven member, said tertiary speed changing mechanism including direct driving connections and intermediate driving connections to said quaternary speed changing mechanism, and driving connections in said quaternary speed changing mechanism between said tertiary speed changing mechanism and said driven member being maintained to transmit power between said driving means and said driven member for all speeds of said driven member and constructed to obtain substantial geometric progression throughout said last-named speeds.

3. In gearing of the character described, the combination of a driving means, a driven member, primary speed changing mechanism, secondary speed changing mechanism, tertiary speed changing mechanism and quaternary speed changing mechanism serially arranged between said driving means and said driven member and transmitting power from said driving means to said driven member at twenty-four selective speeds during employment of all said speed changing mechanisms as transmitting elements for all said speeds.

4. In gearing of the character described, the combination of a driving means, a driven member, primary speed changing mechanism, secondary speed changing mechanism, tertiary speed changing mechanism and quaternary speed changing mechanism serially arranged between said driving means and said driven member and transmitting power from said driving means to said driven member at selective speeds during employment of all said speed changing mechanisms as transmitting elements as so serially arranged for all said speeds, and said tertiary speed changing mechanism including two legs of power through a plurality of shafts including a jack shaft to said quaternary speed changing mechanism and all the shafts of said plurality of shafts rotatable during all said speeds.

5. In combination, gearing comprising a spindle to be rotatively driven at different speeds, a drive shaft, an intermediate driven shaft driven thereby at selective speeds, a back shaft, a jack shaft, releasable drive connection between said intermediate driven shaft and said back shaft and between said intermediate driven shaft, said jack shaft and said back shaft to selectively drive said back shaft immediately from said intermediate driven shaft while said jack shaft is in rotative connection with said intermediate driven shaft and mediately through said jack shaft throughout the speed changes of said spindle, and speed change gearing between said back shaft and said spindle to selectively impart different speeds to said spindle from said back shaft.

6. In combination, gearing of the character described comprising a driven rotatable member, a drive shaft, an intermediate driven shaft, speed changing means between said drive shaft and said intermediate driven shaft to impart different speeds of rotation to said intermediate driven shaft, a back shaft, a jack shaft, shiftable driving connections between said intermediate driven shaft, said back shaft and said jack shaft to drive said back shaft throughout all speed changes of said driven rotatable member selectively direct from said intermediate driven shaft during idle drive rotation of said jack shaft and intermediately from said intermediate driven shaft through the medium of said jack shaft to impart different speeds of rotation to said back shaft, and pluri-speed gearing between said back shaft and said driven rotatable member to impart different speeds of rotation to said driven rotatable member.

7. In combination, gearing comprising a spindle, a drive shaft of highest speed, an intermediate driven shaft, speed changing means driven serially from said drive shaft and serially stepping down the speeds from said drive shaft to said intermediate driven shaft, a back shaft, a jack shaft and releasable drive connecting means including gearing between said intermediate driven shaft, said jack shaft and said back shaft to drive said back shaft selectively direct from said intermediate driven shaft or immediately through said jack shaft at different speeds throughout all power transmissions to said spindle, and speed change gearing between said back shaft and said spindle to selectively impart different speeds to said spindle from said back shaft, said different speeds being serial step down speeds relative to the speed of said drive shaft so related as to superpose gear reductions between said drive shaft and said spindle upon said spindle to rotate said spindle at different speeds arranged in steps which increase from their lowest to their highest speeds in substantial geometric progression.

8. In combination, head stock gearing comprising a spindle, a drive shaft of highest speed, an intermediate driven shaft, two sets of speed changing means driven serially from said drive shaft and serially stepping down the speeds from said drive shaft to said intermediate driven shaft, a back shaft, a jack shaft, releasable means to operatively direct connect said back shaft with said intermediate driven shaft to drive said back shaft at substantially the speed of said intermediate driven shaft and releasable gearing between said intermediate driven shaft, said jack shaft and said back shaft to drive said back shaft from said intermediate driven shaft at reduced speed, so arranged that said back shaft and said jack shaft are rotatable throughout all speed changes, and speed change gearing between said back shaft and said spindle to selectively impart speeds to said spindle substantially equal to and less than the speed of rotation of said back shaft, whereby to superpose successive gear reductions between said drive shaft and said spindle upon said spindle to rotate said spindle at different speeds arranged in steps which increase from

their lowest to their highest speeds in substantial geometric progression.

9. In combination, head stock gearing comprising a spindle, a drive shaft, an intermediate driven shaft, two sets of speed changing means driven serially from said drive shaft and serially changing the speeds from said drive shaft to said intermediate driven shaft, a back shaft, releasable means to operatively directly connect said back shaft with said intermediate driven shaft to drive said back shaft at the speed of said intermediate driven shaft, and a jack shaft and releasable drive connections including gearing between said intermediate driven shaft, said jack shaft and said back shaft to drive said back shaft, all constructed and arranged whereby from said intermediate driven shaft throughout all speed changes of said spindle, and speed change gearing between said back shaft and said spindle to selectively impart different speeds to said spindle from said back shaft throughout all speed changes, in manner to superpose said gear changes between said drive shaft and said spindle upon said spindle to rotate said spindle at different speeds.

10. In combination, head stock gearing comprising a spindle, a drive shaft, an intermediate driven shaft, two sets of speed changing means driven serially from said drive shaft and serially changing the speeds from said drive shaft to said intermediate driven shaft; a back shaft, releasable means to operatively directly connect said back shaft with said intermediate driven shaft to drive said back shaft at the speed of said intermediate driven shaft, and a jack shaft and releasable drive connections including gearing between said intermediate driven shaft, said jack shaft and said back shaft, to drive said back shaft from said intermediate driven shaft throughout all speed changes of said spindle; and speed change gearing between said back shaft and said spindle to selectively impart different speeds to said spindle from said back shaft throughout all speed changes, whereby to superpose said gear changes between said drive shaft and said spindle upon said spindle to rotate said spindle at different speeds, said different speeds arranged in steps which increase from their lowest to their highest speeds in substantial geometric progression having ratio factors in a range substantially of 1.18 to 1.20.

11. In a lathe, the combination of a rotatable spindle, speed change gearing for rotating said spindle at selective speeds, and feed change gearing for the carriage operated by said spindle and comprising a transmitting shaft, a pinion journaled thereabout, a combined clutch and gear element rotatable with and slidable along said shaft for clutching engagement between said journaled pinion and said shaft for coarse feed transmission, and feed reducing gearing between said journaled pinion and the gear portion of said combined clutch and gear element with which said combined clutch and gear element is arranged to be meshed for ordinary transmission.

12. In a lathe, the combination of a rotatable spindle, speed change gearing for rotating said spindle at selective speeds, reversing gearing driven by the spindle, and feed change gearing driven in opposite directions by the reversing gearing and having feeding connections with the feed screw and the feed rod for the carriage, said feed change gearing comprising a transmitting shaft transmitting to said feed screw and said feed rod, a pinion journaled thereabout, a combined clutch and gear rotatively connected with and slidable lengthwise along said shaft, and spaced apart gears meshed respectively by said journaled pinion and arranged to be meshed by said combined clutch and gear element by such lengthwise sliding along said shaft in one direction to transmit lower speed to said feed screw and said feed rod, and endwise movement of said combined clutch and gear element in the opposite direction placing the clutch portion thereof in clutching relation with said journaled pinion and the gear portion thereof in idle relation between said spaced apart gears to transmit higher speed to said feed screw and said feed rod.

13. In a lathe, the combination of a head stock, a spindle journaled therein, feed reversing gearing in said head stock having gear connection with said spindle and provided with a transmitting gear outside said head stock, a feed box for the feed screw and feed rod for the carriage, said feed box having a receiving gear at the outside thereof, and a gear box between said head stock and said feed box having a feeding train therein including a coarse feed train and having gears at the respective ends thereof including quadrant gearing at one of said ends arranged to be meshed with said transmitting gear and said receiving gear respectively, and means to selectively attach said gear box to said head stock and said feed box respectively for correct meshing between said gears.

14. In a lathe, the combination of a head stock, a spindle journaled therein, feed reversing gearing in said head stock having gear connection with said spindle and provided with a transmitting gear outside said head stock, a feed box for the feed screw and feed rod for the carriage, said feed box having a receiving gear at the outside thereof, and a gear box between said head stock and said feed box having a feeding train therein including a pinion meshing with said transmitting gear and having a clutch forming extension, a combined clutch and gear element connectible with said clutch forming extension for coarse feed transmission and reducing gears in train with said pinion and with which said combined clutch and gear element is meshed by shifting the same from said clutch forming extension for ordinary feed transmission, and quadrant gearing driven thereby and meshable with said receiving gear, and means to selectively attach said gear box to said head stock and said feed box respectively for correct meshing between the pinion and quadrant gearing thereof with said receiving gear and said transmitting gear respectively.

15. In speed change gearing of the character described, the combination of a reversing speed change shaft, a reversing clutch shaft, a pair of friction clutches about the latter respectively having drive connections in opposite directions with said reversing speed change shaft, a clutch collar about said clutch shaft movable in opposite directions lengthwise of said clutch shaft for clutch connections in said respective clutches and for neutral relation in both said clutches, a brake having operative connection with said reversing speed change shaft normally in braking position, an operating arm for said clutch collar normally in position of release of said clutches, and a shiftable connection between said operating arm and said brake to release said brake upon movement of said operating arm in both of opposite

directions for clutch connections in said respective clutches.

16. In speed change gearing of the character described, the combination of a drive friction clutch, speed change gears driven thereby, a brake for the latter, an operating arm for said clutch and a multi-link operating connection the links whereof are extended in sequence from said arm between said operating arm and said brake to engage said clutch and release said brake by movement in one direction of said operating arm, and to release said clutch and engage said brake by movement in the opposite direction of said operating arm.

17. In speed change gearing of the character described, the combination of a pair of friction drive clutches and speed change gears driven thereby in opposite directions, a brake for the latter, an operating arm operable in opposite directions to clutch said respective clutches, and a multi-link operating connection the links whereof are extended in sequence from said arm between said operating arm and said brake to release said brake by movements in both directions of said operating arm, and to release said respective clutches and engage said brake by movements respectively in opposite directions of said operating arm.

18. In speed changing mechanism, a pair of shiftable power transmission elements for effecting speed change, and means for shifting said elements comprising a pair of gears respectively having operative connections with said respective elements for shifting the same, and a segment gear positioned for selective meshing relation of its teeth with the teeth of said respective gears for selective rotations of said gears to position said respective shiftable power transmission elements in selective power transmission relations.

19. In speed changing mechanism, a pair of shiftable power transmission elements for effecting speed change, and means for shifting said elements comprising a pair of gears respectively having operative connections with said respective elements for shifting the same, a segment gear positioned for selective meshing relation of its teeth with the teeth of said respective gears for selective rotations of said gears to position said respective shiftable power transmission elements in selective power transmission relations, a locking part coaxial with said segment gear in the angle extended of that portion of said segment gear free of transmitting teeth and rotatable with said segment gear, and a locking part coaxial with and rotatable with each of said gears, each of said last-named locking parts provided with an angular recess in which said first-named locking part is located during meshing relation of the teeth of said segment gear with the gear of said pair of gears coaxial with the other of said second-named locking parts.

20. In speed changing mechanism, shiftable power transmission members for effecting speed change, angularly movable control handles for said respective members to control the positions of said respective members by the angular positions of said respective handles to obtain various resultant speeds, and an index on which resultant speeds and corresponding handle positions in association therewith are pictured to show the positions said handles must assume to obtain such respective speeds.

21. In speed changing mechanism, a shiftable power transmission member for effecting speed change, an angularly movable control handle for said member to control the positions of said member by the angular positions of said handle to obtain various resultant speeds, and an index on which resultant speeds of such speed changes are shown in association with portrayals of said handle in the angular positions to effect such resultant speeds to show the positions said handle must assume to obtain such respective speeds.

22. In speed changing mechanism, shiftable power transmission members for effecting speed change, angularly movable control handles for said members to control the positions thereof indicated by the angular positions of said handles, and an index on which resultant speeds of such speed changes are shown columnwise in association with portrayals of said handles in the angular positions to effect such resultant speeds.

23. In speed changing mechanism, shiftable power transmission members for effecting speed change, angularly movable control handles for said members to control the speed transmitting positions thereof indicated by the angular positions of said handles, and an index on which resultant speeds of such speed changes are shown cross columnwise in association with portrayals of said handles in angular positions to effect such resultant speeds.

24. In speed changing mechanism, the combination of a plurality of speed changing elements for changing speeds in the same power train, and shifting means for said elements comprising a pair of handles having concentric axes, one of said handles having operative connection with one of said speed changing elements and another of said handles having operative connections with a plurality of said speed changing elements to change the ultimate speeds of the speed changing mechanism, said last-named operative connections including a segment gear and an interlock part in the angle extended of that portion of said segment gear free of transmitting teeth rotatable about said axes, and coacting gears and coacting interlock parts coacting with said segment gear and said first-named interlock part selectively at different angular positions of said segment gear and said first-named interlock part.

25. In speed changing mechanism, a plurality of shiftable power transmission elements for effecting speed change, a plurality of rotatable operating parts for shifting said elements, a rotatable operating element having selective operative connections with said rotatable operating parts, a locking part about the latter, said rotatable operating element including a pivot member, and a handle pivoted to said pivot member and angularly movable to rotate said rotatable operating element, said handle provided with a locking part coacting with said first-named locking part to angularly position said rotatable operating element for selective speed changes.

26. In headstock gearing, the combination of the spindle, an intermediate driven shaft having a plurality of speeds of rotation, an additional driven shaft, speed changing means between said additional driven shaft and the spindle including a shiftable speed changing member, a shiftable combined clutch and gear member and coacting parts therefor between said driven shafts to transmit a plurality of speeds to said additional driven shaft, said last-named shiftable member placeable in neutral position, a plurality of rotatable operating parts for selectively shifting said shiftable members, a rotatable operating ele-

ment having selective operative connections with said rotatable operating parts, and a handle angularly movable to rotate said rotatable operating element, coactive locking parts respectively stationarily positioned about the axis of said rotatable operating element and positioned on said handle coactive in positions to locate each of said shiftable members in a plurality of speed transmitting positions and to locate said shiftable combined clutch and gear member in neutral position with relation to both of said driven shafts for severing power transmission to said spindle to enable manual rotation of said spindle.

27. In speed changing mechanism, the combination of a plurality of shiftable power transmission elements each shiftable into a plurality of positions for effecting speed change, and combined means for shifting said respective elements so related as to hold said power transmission elements simultaneously away from one of their speed change positions to limit the number of speed changes transmittable by said shiftable power transmission elements.

28. In speed changing mechanism, the combination of a plurality of shiftable power transmission elements each shiftable into a plurality of positions for effecting speed change, combined means for shifting said respective elements so related as to hold said power transmission elements simultaneously away from one of their speed change positions to limit the number of speed changes transmittable by said shiftable power transmission elements, a control handle for said combined means, and a positioning part for said control handle positioning a power transmission element named in neutral position.

29. In speed changing mechanism, the combination of a pair of shiftable power transmission elements each shiftable into two positions for effecting speed change, and means for shifting said elements comprising a pair of gears respectively having operative connections with said respective elements for shifting the same and a segment gear positioned for selective meshing of its teeth with the teeth of said respective gears for rotating the latter, an operating handle for said segment gear, a positioning part therefor and a locating part provided with coacting parts for said positioning part angularly placed about the axis of rotation of said handle to locate said power transmission elements in selective power transmission relations and so arranged as to eliminate one of said power transmission relations.

30. In speed changing mechanism, the combination of a pair of shiftable power transmission elements each shiftable into two positions for effecting speed change, and means for shifting said elements comprising a pair of gears respectively having operative connections with said respective elements for shifting the same and a segment gear positioned for selective meshing of its teeth with the teeth of said respective gears for rotating the latter, coacting interlocks rotatable respectively with said segment gear and said respective gears to relate the meshing relation of said segment gear with said respective gears of said pair of gears for controlling said positions for effecting speed change and to lock said shiftable power transmission elements from simultaneous positioning of each of said power transmission elements in a given power transmitting position to limit the number of power transmission relations of said pair of shiftable power transmission elements.

31. In speed changing mechanism for a lathe, the combination of a spindle, friction reducing bearings at one end thereof to hold said spindle in axial direction at said end, speed change gearing fixed to said end of said spindle, a transmitting gear on the other end of said spindle, a bearing for said spindle at its said other end, a bushing in which said last-named bearing is located, and a bearing for said bushing, said bushing movable in axial direction in said last-named bearing to compensate for lengthwise heat expansion and contraction of said spindle.

32. In speed changing mechanism for a lathe, the combination of a spindle, friction reducing bearings at one end thereof to hold said spindle in axial direction at said end, speed change gearing fixed to said end of said spindle, a transmitting gear on the other end of said spindle, a bearing for said spindle at its said other end, a bushing in which said last-named bearing is located, a bearing for said bushing, said bushing movable in axial direction in said last-named bearing to compensate for lengthwise heat expansion and contraction of said spindle, and a spring between said last-named bearing and said bushing to urge said bearing for said spindle at said other end of said spindle toward said speed change gearing.

33. In speed changing mechanism for a spindle, the combination of a plurality of pairs of shiftable speed changing elements arranged in sequence in the transmission, a pair of shifting means for the respective elements of each of said pair of shiftable speed changing elements respectively including a pair of crank pins for shifting said respective elements of each pair and a pair of locking means for said crank pins of said respective pairs, said locking means for each pair of crank pins locking one of the crank pins when releasing the other of the crank pins of said pair of crank pins, and so constructed that said locking means for one of said pair of crank pins locks the elements of the pair of shiftable speed changing elements operated thereby selectively in idle relation, and said locking means for the other of said pair of crank pins locks the elements of the pair of shiftable speed changing elements operated thereby selectively in transmission relation.

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