A. L. DE LEEUW.

FEED MECHANISM FOR MACHINE TOOLS.

APPLICATION FILED OCT. 31, 1910.

1,108,107.

Patented Aug. 18, 1914.

3 SHEETS—SHEET 1.

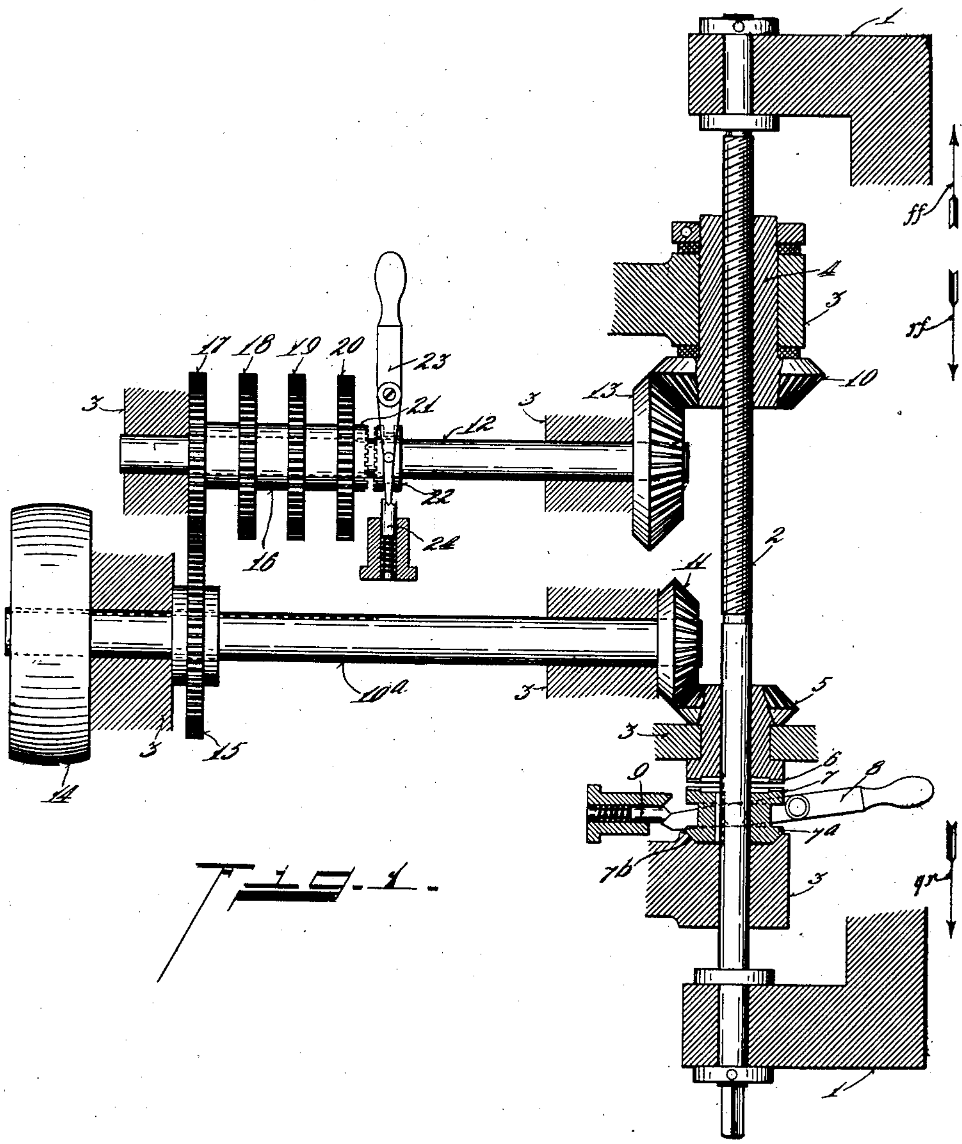

Fig. 1.

Witnesses

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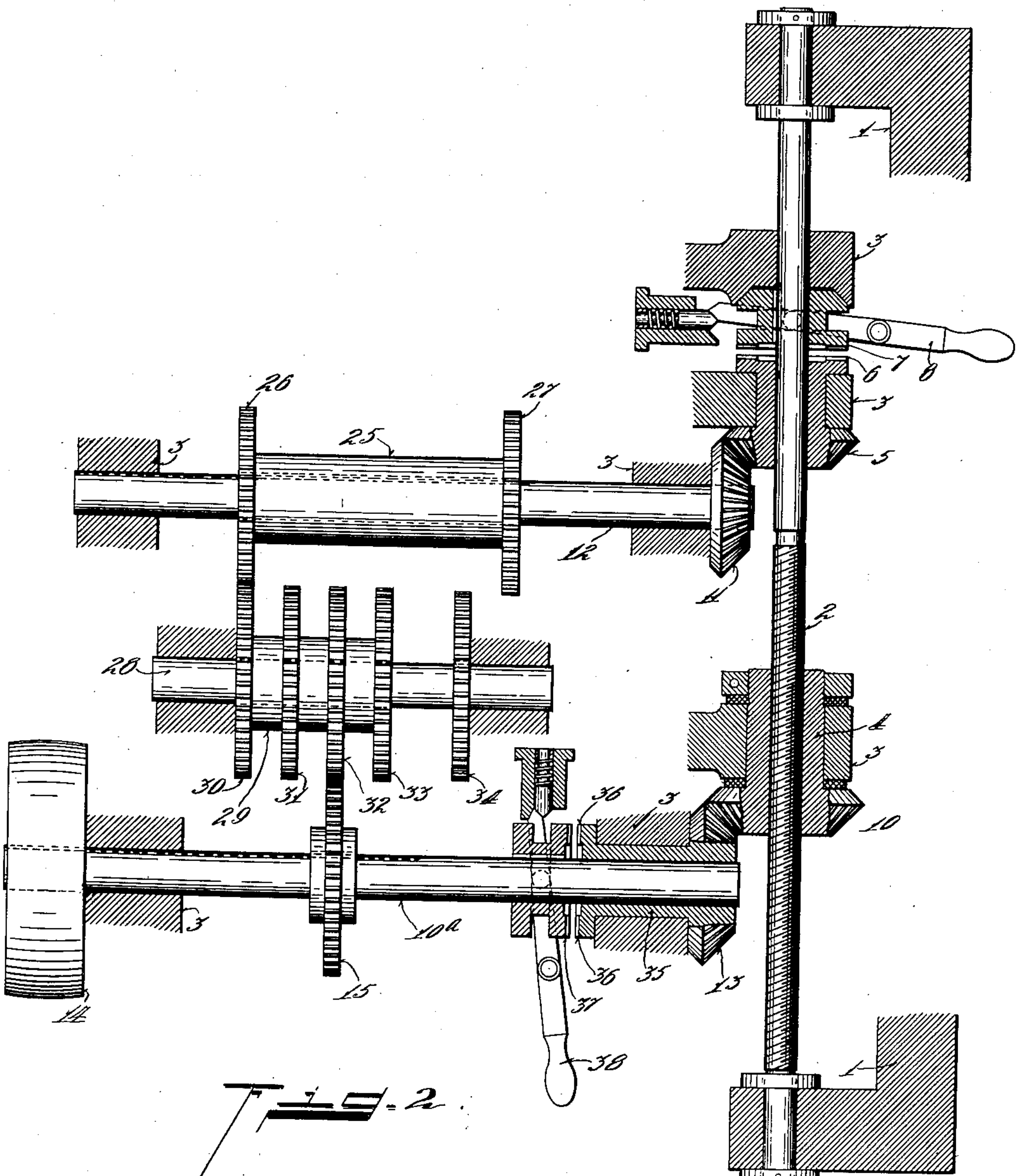

Fig. 2.

Witnesses

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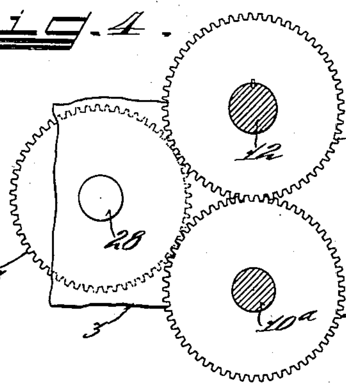
3 SHEETS—SHEET 3.

Fig. 4.



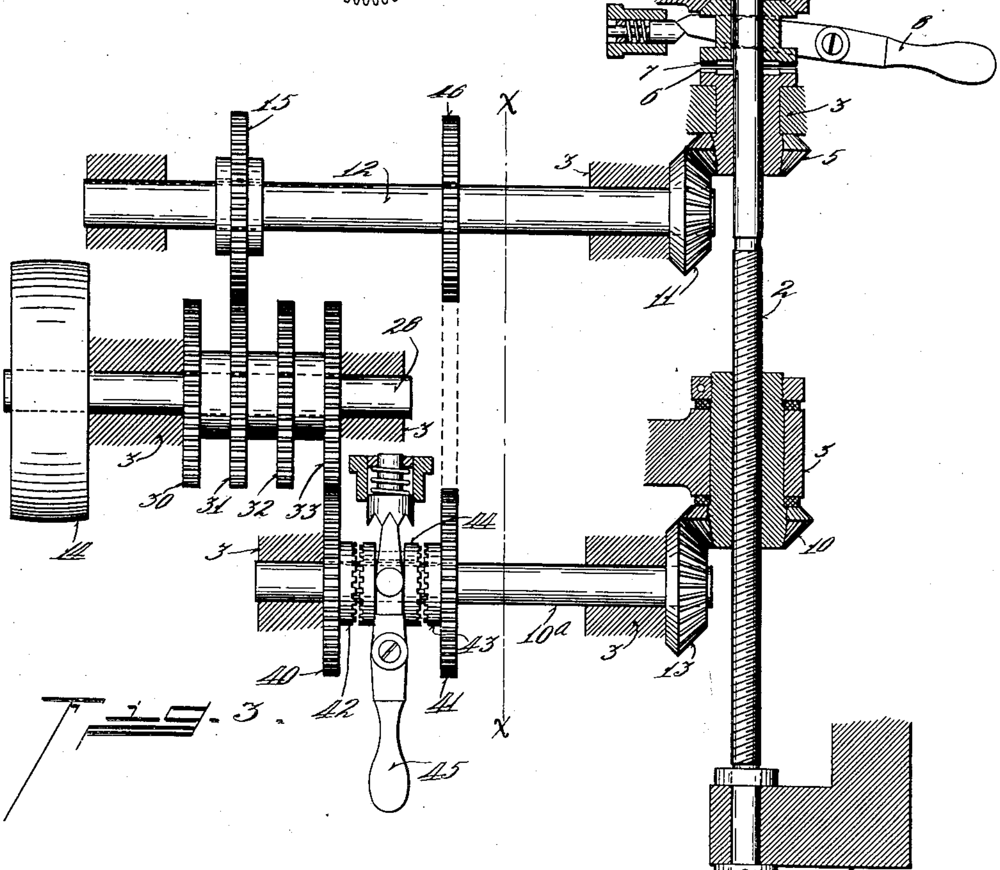


Fig. 3.

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FEED MECHANISM FOR MACHINE-TOOLS.

1,108,107. Specification of Letters Patent. **Patented Aug. 18, 1914.**

Application filed October 31, 1910. Serial No. 589,913.

To all whom it may concern:

Be it known that I, ADOLPH L. DE LEEUW, a citizen of the United States, residing at Cincinnati, in the county of Hamilton and State of Ohio, have invented certain new and useful Improvements in Feed Mechanism for Machine-Tools, of which the following is a specification.

This invention deals with an improved positive-drive mechanism affording a diversity of feed speeds that are selectively available to propel an element in such a direction and during such a time as may be predetermined by the user.

Certain machine tools demand a slow travel of the tool while it is cutting the work, and efficiency requires the tooling speed to be as great as will be permitted by the strength of the tool or machine and by the power available. A range of feed changes should therefore be provided, and to enable the maximum working speed to be attained as approximately as is practical without involving undue complexity by too many different speeds, the gaps between the different speeds must be pronounced, *i. e.*, quite large in proportion to the speeds, without, however, being excessive. This obtains especially with milling machines used for steady manufacturing on work of one variety. Thus, the speeds may progress in an arithmetical, geometrical or harmonic series of a normal or "mean" character (as 1—2—3—4 or 10—9—8—7 or 1—2—4—8, etc.) in which the percentage variation in values between the successive members is substantial, and neither immoderate nor immaterial as in "extreme" or abnormal series. In practice, less than a 10% variation (as in the normal series 11—10—9—8) will seldom be desirable, and ordinarily a series of a spacing still more open in a relative sense (as 4—3—2—1 in which the gap-values range from 100% to 33%) will be preferred. An "extreme" series of the "crowded" or congested type (as 50—49—48—47) would be quite unsatisfactory for actual tooling feed changes because the percentage variation—being only about 2% or less—is not sufficiently accumulative within the limited number of feed changes obtainable with simple constructions of positive-drive change-gears, such as practice and commercial considerations call for; and in like manner an "extreme" series of the "diffuse" type (as 1—4—16—64) would also be unsatisfactory as the jumps in relative feeds are too excessive for purposes of practical approximation of the logical working speed.

By a normal or "mean" series is meant any series in which the average percentage variation between the successive members will be not more than about 100% or less than say 10%, as for example the series 1—2—4—8 or the series 22—20—18—16 which latter is finally reducible, by means of a common divisor, to the series 11—10—9—8 located substantialy at the units end of the numerical scale and has members represented by simple digits or digital values. By an "extreme" or abnormal series is meant one in which the percentage variation will be quite disproportionate with the speeds, either exaggerated as in a "diffuse" series or immaterial as in a "crowded" series, as for example several hundred per cent. on the one hand or about 2% or less on the other hand and which cannot be reduced to terms corresponding to simple digital values, but in which certain of the members will lie well within the tens or hundreds groups or otherwise high in the numerical scale; as the series 50—49—48—47.

Heretofore an ample range of speed-changes has been commercially obtained by means of an ordinary tumbler type of change gear (a "mean" series shift) involving a cone of gears, but this arrangement is complex, expensive and bulky. The usual cone of gears, being characteristically a mean or normal series, however, has the advantage that it directly yields the desirable properly graduated gaps in the gear ratios so that in actual practice the ultimate feed-speeds will merely represent a direct multiple of the cone-gear ratios. This feed change alone, however, is not all that is required, but other considerations have to be provided for and reconciled therewith. That is to say, in addition to the variable-speed slow tooling movement, it is desirable to provide for certain idle fast travels, as a fast travel to the work and a fast return to the starting-point. These fast idle forward and return movements have been secured in various ways; the simplest perhaps proposed heretofore being that of the Kellemen Patent No. 957,562, which suggests a nut-and-screw arrangement providing a fast travel in two directions and a slow travel in one direction, but without any component means for varying the speed of the slow travel or for altering its direction.

An earlier patent to McClellan No. 533,997, suggests a rather complex and scattered nut-and-screw arrangement involving three very long non-traveling shafts (power, splined and screw) together with sundry traveling elements including a nut and pinion. An ordinary stationary cone change-gear provides a "mean" or normal series of speed changes which are available as such only when the screw alone is turning, *i. e.*, during the fast idle travel (when they are not wanted) and which are not available without a radical change in character to an "extreme" or abnormal series (when they are useless) when both nut and screw turn to give a slow speed. In other words, an ordinary change-gear must be shifted in and out of series with the transmission, otherwise it would introduce excessive changes in the rate of the quick traverse when the changes were made in the rate of the "feed" speeds. This means that a differential movement system with an ordinary change-gear in one of its two parallel-series transmissions could not be used to obtain marked changes at slow speeds and imperceptible changes at fast speeds, in any practical way, so any such "combination" is not coöperative in a machine-tool sense.

Now, this invention proposes a still different combination based in part upon the novel conception that a change-gear directly yielding an abnormal "crowded" series of speeds may be so coördinated with a differential movement arrangement, such as a nut-and-screw system, that its speed values may be ultimately translated into a "mean" or normal series available as such during the slow feeding or working periods (exactly when needed) and based in further part upon the creation of an extremely simple yet positive change-gear structure of the "crowded" series type which is especially suitable for coöperation with a differential movement such as the nut-and-screw system in attaining the unique practical transformation of values as stated, and which will structurally harmonize with the differentially-movable elements to afford all essential forward and reverse speed conditions. A distinctive characteristic of this unique combination is that motion may pass through the change-gears as well for the feeds as for the quick traverses.

One distinct object within the contemplation of this invention is to render available an organization of related elements whereby a very simple and smoothly operable change-gear directly yielding an abnormal "crowded" series of gear ratios will be given the capacity of ultimately positively propelling a traveling part, such as a table, at tooling speeds selectively progressing in a "mean" or normal series, of any desired species, such as the arithmetical series 2—4—6—8.

Another distinct object of this invention is to devise a simple yet wholly positive system of mechanical elements for producing alternately a slow movement suitable for tooling purposes and a fast movement suitable for idle movements; said system embodying control mechanism whereby the slow movement may be selectively accelerated step-by-step by positive moderate increments each having a value of not less than 10% of the previous slow speed rate, and whereby the said pronounced speed changes of the slow movement, will not necessitate proportionate variations in the fast movement so that the increments of the latter need not exceed the normal fast rate by more than about 2%, and thus be inconsiderable.

Another object is to simplify and render more positive the change from a slow motion to a fast motion by splining a shiftable clutch member onto the screw or an extension thereof and constructing it to bear against a stationary part in one position to brake the screw against turning, and to engage a continuously rotating member in its other position positively to transmit rotary motion to the screw.

Other objects will be in part obvious from the annexed drawings and in part indicated in connection therewith by the following analysis of this invention.

This invention accordingly consists in the features of construction, combinations of parts, and arrangements of elements deducible herefrom, and in the unique relations of the members and in the relative proportioning and disposition of the motion ratios thereof; all as more completely outlined herein.

To enable others to grasp the characteristic principles underlying this invention so clearly that they may readily embody the same throughout the range of modification to which it is subject, drawings diagrammatically revealing the same have been appended as a part of this disclosure, and in such drawings, like characters of reference denote corresponding parts throughout all the views, of which:—

Figure 1 diagrammatically exemplifies an elementary embodiment of this invention, affording a slow tooling translation providing a normal or "mean" series of speeds progressing in a harmonic series, and also affording a fast reverse idle traverse when the nut is still, and a fast idle forward traverse when the screw is still. Here the screw rotates at constant speed and the nut at a variable speed. Fig. 2 diagrammatically exemplifies another embodiment of this invention affording a slow tooling translation and providing a "mean" series of more extensive speed changes in slow movement and affording a fast idle traverse both in advance and in retreat with relation to the slow tooling movement. Here a supplementary ratio 34—27 may be inserted and the nut rotates at constant speed and the screw at variable speeds. Fig. 3 diagrammatically exemplifies another arrangement for attaining further variations, and shows an arrangement of the series of gears in such a relation that theoretically true arithmetical and geometrical series of speeds may be obtained. Fig. 4 is a section on line *x*—*x*, of Fig. 3.

Continuing now by way of a more detailed description, it will be convenient first briefly to catalogue the mechanical elements representing this invention.

The table is indicated by 1 and typifies the element ultimately to be moved rapidly either backward or forward to bring the cutting tool or the work into the desired positional relationship, and to be moved at other times slowly (with speed change capacities) during the actual working or tooling operation. This element receives its fast movements by the individual rotation of either the nut, or the screw alone, as shown in the arrangement of Fig. 1, and it receives its slow movement by the differential unidirectional movements of said parts.

The screw is indicated by 2 and is preferably rotatably journaled on the traveling table or support 1 to translate therewith and the length of the screw in that case represents the length of stroke possessed by the table. This screw at all times freely translates with the table, but at certain times simultaneously rotates and translates; and at other times non-rotatably translates. It will be evident that the screw may have any desirable pitch, say about a pitch of one-half an inch.

The screw-rotator and brake is exemplified by the part 7 splined to the screw so as to rotate therewith while permitting of relative axial movement therewith and having at one end clutch teeth for establishing connection with the source of rotary power, and at its other end having a cone braking surface 7^a, adapted to contact with a suitable seat 7^b in the stationary part 3 and thus stop the rotation of the screw by means of friction.

8 represents a shifting lever for the clutch 7, and 9 indicates a snap pin for resiliently urging the shifting parts into one or the other of their extreme positions. Journaled in proximity with the screw, as by being concentrically mounted thereon, is a gear 5 adapted to be brought into driving engagement with the splined member 7, as by means of the teeth 6, so that when the parts are in the one shifted-position, the screw will be positively rotated by motion derived from the gear 5. This gear may in turn receive motion by means of a suitable power transmission, here represented by the shaft 10^a, and the gear 11, both of which ultimately receive power as from pulley 14.

The nut is represented by 4 and is journaled in the stationary frame 3 to have a unidirectional movement, *i. e.* it may freely turn and yet may not translate, and this nut engages the threads of the screw 2, so that the longitudinal position of the latter is determined by its rotary relation with the nut 4.

The means for rotating or stopping the nut comprises a constantly rotating part as 21, and a shifting clutch member as 22 actuated by the lever 23 held in its extreme positions by the spring-pressed pin 24. Conveniently, the clutch 22 may be concentric with the shaft 12 which is connected with the nut by means of gears 10 and 13.

It will be perceived that the means thus far described enable either the nut or the screw alone to be rotated from a suitable source of power, which will produce a rapid traverse of the table, and it will also be seen, if the nut and screw be rotated simultaneously in the same direction but at different speeds, that the table may be caused to move slowly in a direction determined by the member which gains speed on the other. The means for doing this will now be described.

The differential rotator for the nut and screw is exemplified by gears 15 and 17, the former of which is driven by the shaft 10^a, the latter being fast to the sleeve 21 and meshing with the former. To secure a differential motion these gears will have different numbers of teeth, assuming that the bevels 5 and 11 and the bevels 10 and 13 are both in even ratio or an unequal ratio may be introduced at some other point. Thus, the gear 15 may have 60 teeth and the gear 17, 59 teeth. By this means, the nut and the screw may be driven in the same direction but at slightly different speeds, so that the resultant relative movement therebetween will be a slow movement, which will be imparted to the table as by means of the screw 2. In the instance of Fig. 2, the nut is the more rapidly rotated part. It will be noted that the parts thus far described do not permit of any change in speed of the table during the said slow movement, assuming that the pulley 14 rotates at a constant speed. This invention, however, embodies a peculiar means for varying the slow speed step-by-step at a normal series exactly suitable for obtaining the maximum tooling efficiency.

The crowded-series change gears proposed by this invention constitute a unique instrumentality for obtaining properly graduated feed changes of the table during the slow travel of the latter. Fixed to the sleeve 21 are several other gears 18, 19 and 20 preferably equal in diameter with the gear 17, but differing progressively therefrom step-by-step by relatively few teeth. Thus, the gear 17 may have 59 teeth, the gear 18 have 58 teeth, the gear 19 have 57 teeth and the gear 20 have 56 teeth, so that by sliding the gear 15, having 60 teeth, it may be brought in succession into mesh with the several gears. This interposes in succession between the nut and screw the speed ratio $\frac{60}{59}$ equal to 1.016; or the ratio $\frac{60}{58}$ equal to 1.033; or the ratio $\frac{60}{57}$ equal to 1.051; or the ratio $\frac{60}{56}$ equal to 1.070. Assuming that the pulley fixed to the shaft 10^a rotates at 240 r. p. m., the said gears will therefore rotate at speeds (17) 244.1; (18) 248.3; (19) 252.7; (20) 257.2.

It will be seen that the series 1.016—1.033—1.051—1.070 or any multiple thereof, as the series of absolute revolutions 244.1—248.3—252.7—257.2, is of itself of no practical value for directly varying cutting speeds since the successive values differ but little proportionally from one another. That is, the second member is here but 1.8% greater than the first; the third term is but 1.7% greater than the second; etc. Such a series is essentially an abnormal one from the aspect of conventional speed-change gears, since the ratios are too crowded proportionally or congested to be of value for actual cutting speeds, and therefore is in sharp contradistinction from normal speed-change gears in which the successive steps are never so far apart as to be useless for purposes of reasonable approximation as the best speed, or so crowded as to afford no extended range without requiring a great and undue multiplicity of parts and excessive structural complexity. I have discovered, however, that a certain one of three conceivable types of change gears, *i. e.*, what I have termed the "crowded" one of the two abnormal types, may be combined in a certain one of the many possible arrangements with a nut and screw, *i. e.*, when the nut and screw rotate unidirectionally and simultaneously with my type intervening, so that the slow travel of the table may be varied in moderate yet appreciable steps by gear-shifts of a comparatively inappreciable nature, and yet without appreciably varying the fast backward or forward travel, when either the nut or screw alone is rotated and without shifting the change gears. This will be understood by referring to the above mentioned crowded gear ratios and noting that they are selectively available in the nut and screw combination when both the nut and screw rotate in the same direction at a predetermined normal gear ratio that is unity in the examples herein described. In this way, each of the ultimate speeds instead of being related in direct proportion to the ratio plus the absolute speed increment, is related in about direct proportion to the isolated speed increments, thereby obtaining a normal series, thus:—

$1016-1000=16$		1
$1033-1000=33$	Nearly same	2
$1051-1000=51$	relation as	3
$1070-1000=70$		4

It may be noted that this series very closely approximates an elementary arithmetical series, though derived from a harmonic series, and it will be evident that the primary series may be any regular series such as a geometrical, or arithmetical series as employed by Fig. 3.

By rendering a "crowded" series change-gear usefully available for varying tooling speeds, this invention has at once made possible a pronounced independent simplification of the change-gear structure, and as a further improvement I have brought into the screw and nut combination a peculiar species of change gears consisting of a number of gears of equal diameters rotating concentrically as a unit and having a comparatively large number of teeth, but differing from end to end of the series by comparatively few teeth. I have found that for a limited number of such gears, differing, say by one tooth in progression, a single gear may be made to mesh satisfactorily with all, and may thus be splined to a shaft parallel with the axis of said gear series, so that by a simple slide it may be geared with each in succession, thus avoiding tumbler-gears or rocking-shafts, while yet using but one gear as the driving or driven gear, as the case may be. This reduces change-gears to the simplest form. It is to be noted that this unique gear shift is of itself an independent invention and rights to claim the same as a structure isolated from the nut-and-screw or differential feature are expressly reserved for another application; this case claiming the peculiar change gear only as an element in the combinations disclosed.

If the clutches 21 and 22, and clutches 6 and 7 are both in driving engagement, the nut 4 and screw 2 will both be simultaneously rotated at relatively high speeds in the same direction, but as they have differential speeds, or a series of differential speeds, the screw will be movable longitudinally, at a relatively low ratio, thus giving a series of appropriate table feeds. Also, preferably, the gear ratios are so selected that the feeds will increase in arithmetical progression. For instance, with the figures indicated, the table feed would be at the rate of two, four, six and eight inches to the minute for a lead screw of half-inch pitch.

In practical operation, to give the table a fast movement up to the point of cutting, the lever 8 is in position to disengage the clutches 6 and 7, the lever 23 being moved to a position where the clutches 21 and 22 are engaged. Thus the screw 2 will be held against rotation, and the nut 4 will be highly speeded to move the screw longitudinally forward, at a relatively fast travel, say, at the rate of one hundred and twenty to one hundred and twenty-eight inches per minute, depending upon which one of the gears 17, etc., is in commission. When the table arrives at the point of cutting, the lever 8 is moved to engage clutches 6 and 7, and consequently the screw 2, and nut 4, are simultaneously rotated in the same direction, to give the table a feeding movement at the rate of two, four, six and eight inches per minute, depending upon which one of the gears 17, etc., is in commission. After the cutting operation, the lever 23 is moved to disengage the clutches 21 and 22, and, therefore, the nut 4 will be held stationary, while the screw 2 is rotated at a fast speed, thus serving to longitudinally move the screw in a reverse direction, at a high rate of travel, say, one hundred and twenty inches to the minute. It will be seen from this description that to accomplish these different results, only one of the levers, 23, 8, is moved at one time; also, that the rotative elements are never reversed; also, that the toothed clutches being highly speeded, operate instantaneously to control the table movements. To make these actions clearer, assume that the table is feeding, the nut and screw are rotating in the same direction, but the nut being relatively higher speeded than the screw, the resultant influence on the table will be a slow movement in the direction, indicated by the arrow, lettered *f*, *f*, standing for "forward feed." After the cut, the nut is arrested and the screw then moves the table rapidly in the direction of the arrow, lettered *q*, *r*, standing for "quick return." At the end of this movement, the screw is arrested and the table stopped. To advance the table rapidly to the point of the next cut, the nut is thrown into operation, the screw being held against rotation, and at the cutting point, the screw is also thrown into operation.

I will next describe the modification shown in Fig. 2, which comprises an elaboration of the organization shown in Fig. 1, the object being to produce a double number of speeds, obtainable from the simple arrangement, shown in Fig. 1. In Fig. 2, there is a sleeve 25 splined on shaft 12, so as to turn therewith and slide thereon, said sleeve being provided with the equal diameter gears 26, 27, on its opposite ends, but formed with the different number of teeth. 28 represents a counter shaft, suitably journaled in the frame, to which is fixed the sleeve 29. 30, 31, 32 and 33, represent a series of equal diameter but differently toothed gear wheels, fixed on the sleeve 29, and suitably spaced to permit of their being in mesh with the gear 15. 34 represents a gear fixed on the shaft 28. The clutch for controlling the screw driving-nut 4 is placed on shaft 10^a in this instance. The beveled gear 13, for driving the beveled gear 10 is fixed on the sleeve 35, having the end toothed clutch member 36. 37 represents a coöperating clutch turning with and sliding on shaft 10^a, the sleeve 35 being loose on said shaft. 38 represents the lever, for shifting the sliding clutch member. With this arrangement, when the gear 26 engages the gear 30, and both clutches are in position for rotating both the double gears 5, 10, there may be four feeds given the table by appropriately shifting the gear 15, while if gears 26 and 30 are disengaged, and gears 27 and 34 engaged, four different or additional feeds may be given to the table by appropriately shifting the gear 15. Of course, this arrangement also permits of the beveled gears 5, 10, being rotated independently, for producing the fast forward and reverse table movements, but a more ample range of feeds is thus obtained. Of course, in Fig. 2, the arrangement is transposed, so that the beveled gear 13, rotating the beveled gear 10 is placed on the shaft 10^a, instead of on the shaft 12, as in Fig. 1, for operating the screw driving nut; while the beveled gear 11, for rotating the screw is placed on shaft 12, instead of shaft 10^a, as in Fig. 2.

The modification illustrated in Figs. 3 and 4 discloses another amplification of the simple arrangement shown in Fig. 1. In this figure, the sliding gear 15 is placed on shaft 12, instead of shaft 10^a, but as in Fig. 2, it intermeshes with the series of gears 30, 31, 32 and 33, on counter shaft 28, as in Fig. 2, but the driving pulley 14 is disposed on the end of shaft 28. On shaft 10^a are two relatively loose gear wheels 40, 41, having tooth clutch members 42, 43, respectively. 44 represents a coöperating double toothed member turning with and sliding on shaft 10^a, and shifted by lever 45, to fix either of the gears 40, 41, to the shaft 10^a. In this instance, the gear 40 is intermeshed with the gear 33, and the gear 41 is intermeshed with gear 46, fixed on shaft 12, see Fig. 4, shown diagrammatically in Fig. 3, by dotted lines. The nut and screw may be rotated in the same directions at variable speeds, and either may be made the relatively higher speeded element, for feeding in either direction. With this arrangement, if the screw and nut are simultaneously rotated, four speeds may be given to the table in one direction of movement, when the gear 40 is fixed to the shaft 10^a. While gear 41 is fixed to shaft 10^a, four speeds may be given to the table, but in the opposite direction of travel. The intermediate clutch position of the member 44 permits of the independent driving of the screw rotating beveled gear 5. The forward feed of the Fig. 1 arrangement, is obtained by rotating the nut at a higher speed, but in the same direction as the screw. The reverse feed of the Fig. 3 arrangement, is obtained by rotating the screw in the same direction, but at a higher speed than the nut.

In some classes of work, it is very desirable to be able to obtain a table feed in both directions of its movement, and this arrangement also permits of a relatively fast travel of the table in either of its directions of movement.

In the light of this disclosure, those skilled in mechanical arts will be enabled to utilize matters of current knowledge in modifying details of this invention and in adapting the same to meet the requirements of various circumstances, without however departing from the features and combinations which, from the aspect of the prior art, will be found to constitute true characteristics of this invention, and such constructions are thereofore to be regarded as falling within the scope or range of equivalency of the following claims.

While I have designated the longitudinally movable machine element as a "table", its equivalent element would be commonly known under a different technical name where the invention is applied to different varieties of machine tools.

It is obvious that when the screw is rotated and the nut is stationary or locked against rotation, a fast feed is obtainable, the direction of feed depending upon the direction of rotation, and the same is true when the screw is stationary, and the nut is revolved, while a slow feed is obtainable when both are revolved in the same direction with one rotating relatively faster than the other.

The drawings show the clutch adapted to be engaged with the gearing for driving the screw, as concentric with the screw, and arranged so that it will be thrown into driving engagement in one position and in a locked condition in a second position, and it is obvious that the nut could be provided with a clutch to perform a similar operation, viz., engaging with the driving mechanism in one instance, and locking the same against rotation in a second instance, and by mounting such locking means in more or less direct connection with the driven element the same can be more positively maintained against rotation.

The clutches may be of any general or preferred form other than the ordinary tooth form illustrated, which in a broad aspect may be treated as controllers for throwing into and out of operation the various driven elements.

I therefore claim as new and desire to secure by Letters Patent:—

1. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member movable independently of the other; a speed-change means comprising a concentric series of differently toothed gears of equal diameters locked together and coöperating gearing adapted to be selectively meshed therewith by a relative axial shift; a positive motion-transmission connecting said members whereby they may be caused to rotate differentially at a predetermined speed ratio, said transmission including said speed change means, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by relatively small speed increments; an element differentially and mutually actuated by said members; and a traveling support deriving propulsion from said element.

2. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member movable independently of the other; a speed change means comprising at least four gears of equal diameters locked concentrically together and differing in number of teeth in regular progression and a coöperating gear shiftable in axial parallelism with said four gears and adapted to be selectively meshed therewith; a positive motion-transmission connecting said members whereby they may be caused to rotate differentially at a predetermined speed ratio, said transmission including said speed change means, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by relatively small speed increments; an element differentially and mutually actuated by said members; and a traveling support deriving propulsion from said element.

3. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member movable independently of the other; a speed change means comprising a concentric plurality of gears of equal diameters locked together and having their teeth increasing in number in an arithmetical series, and coöperating gearing adapted to be selectively meshed therewith by a relative axial shift; a positive motion-transmission connecting said members whereby they may be caused to rotate differentially at a prdetermined speed ratio, said trans-

mission including said speed change means, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by relatively small speed increments; an element differentially and mutually actuated by said members; and a traveling support deriving propulsion from said element.

4. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member movable independently of the other; a positive motion-transmission connecting said members whereby they may be caused to rotate differentially at a predetermined speed ratio; a selective change means arranged in said transmission and comprising several differently toothed gears of equal diameters, and coöperating gearing adapted to be intermeshed therewith, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by relatively small speed increments; an element differentially and mutually actuated by said members; and a traveling support deriving propulsion from said element.

5. A feed-change mechanism of the nature disclosed combining a traveling support; a power driven member, a nut and a screw for transmitting motion from said member to said support; a positive motion-transmission extending from said member to said nut; a second positive motion-transmission extending from said member to said screw; and a series of gears having different numbers of teeth and equal diameters selectively available in one of said transmissions to vary the transmitting ratio thereof by predetermined small speed increments.

6. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member in screw-threaded relation therewith; a positive motion-transmission connecting said members whereby they may be caused relatively to rotate in the same direction at a predetermined speed ratio; a speed-change device comprising an organized set of closely graduated gears forming a crowded series of ratios selectively available in said transmission, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by speed increments each equal to a very small fraction of the predetermined speed ratio between said two members; a part positively and slowly actuated by one of said members as it moves differentially to the other, whereby the positive speeds at which said part is propelled will be approximately in direct proportion with the corresponding speed increments or multiples thereof, and will each present a large proportional deviation from the speeds nearest it in the series.

7. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member in screw-threaded relation therewith; a positive motion-transmission connecting said members whereby they may be caused relatively to rotate in the same direction at a predetermined speed ratio; a speed-change device comprising an organized set of closely graduated gears forming a crowded abnormal series of ratios selectively available in said transmission, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by speed increments each equal to a very small fraction of the predetermined speed ratio between said two members; a part positively and slowly actuated by one of said members as it moves differentially to the other, whereby the positive speeds at which said part is propelled will be approximately in direct proportion with the corresponding speed increments or multiples thereof, and will each present a large proportional deviation from the speeds nearest it in the series; and means for disconnecting one of said members from said transmission whereby its rotation may be stopped and said part rapidly actuated at fast approximately equal rates each in direct proportion with the sum of one of said increments and said predetermined rate or a multiple of said sum.

8. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member in screw-threaded relation therewith; a positive motion-transmission connecting said members whereby they may be caused relatively to rotate in the same direction at a predetermined speed ratio; a speed-change device comprising an organized set of closely graduated gears forming a crowded series of ratios selectively available in said transmission, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by speed increments each not materially greater than approximately two hundredths of the predetermined speed ratio between said two members; and a part positively actuated by one of said members as it moves slowly relatively to the other, whereby the positive speeds at which said part is propelled will constitute a mean series the values of which are approximately in direct proportion with said speed increments or multiples thereof.

9. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member in screw-threaded relation therewith; a positive driving connection connecting said members whereby they may be caused relatively to rotate in the same direction at approximately the same speed; a speed-change device comprising an organized set of closely graduated gears providing a crowded series of ratios selec-

tively available in said connection, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression from said predetermined ratio by speed increments each equal to a very small fraction of the predetermined speed ratio between said two members; and a part positively actuated by one of said members as it moves relatively to the other, whereby the positive speeds at which said part is propelled will be approximately in direct proportion with the absolute speed increments or multiples thereof.

10. A change speed mechanism for power transmitting machinery comprising in combination with a moving part from which the power is derived and a moved part to which the power is transmitted; a concentric series of differentially toothed gears of equal diameter locked together and operatively connected to one of the aforesaid parts; and gearing operatively connected with the other of said parts and adapted to be selectively meshed with the gears of said concentric series by a relative axial shift.

11. A feed-change mechanism of the nature disclosed combining a translating carriage, a screw rotatably mounted thereon and adapted to translate therewith, a nut rotatably mounted on a relatively stationary part and engaging said screw, a gear loosely concentric with said screw, a clutch-member splined directly to said screw and movable into engagement with said gear to lock the same to said screw, and oppositely movable to engage a fixed part to lock the screw against rotation and to permit said gear to idle on said screw, and means for simultaneously rotating said nut and gear.

12. A feed-change mechanism of the nature disclosed combining a translating carriage; a screw rotatably mounted thereon and adapted to translate therewith; a nut rotatably mounted on a relatively stationary part and engaging said screw, screw-driving gear arranged in position to be operatively connected with said screw and normally rotatable independently therefrom; and a rotary member splined directly to said screw and adapted to be shifted thereon to engage said gear and operatively connect it with said screw; a positive motion-transmission for simultaneously rotating said nut and said gear; and a speed change gear in said transmission.

13. A feed-change mechanism of the nature disclosed combining a translating carriage; a screw rotatably mounted thereon and adapted to translate therewith; a nut rotatably mounted on a relatively stationary part and engaging said screw, a gear loosely concentric with said screw; a clutch member splined directly to said screw and movable into engagement with said gear to lock the same to said screw; and oppositely movable to engage a fixed part to lock the screw against rotation and permit said gear to idle on said screw, a positive motion transmission for simultaneously rotating said nut and gear; and a change gear in said transmission.

14. A feed-change mechanism of the nature disclosed combining a traveling support; a power-driven member; two actuated parts, the one being a nut and the other being a screw, for transmitting motion from said power-driven member to said support; a long multiple-part positive motion-transmitting connection extending indirectly from said member to one of said parts whereby it may be actuated; a short positive driving connection extending directly from said member to the other of said parts whereby it may be actuated; means in the said long indirect connection for discontinuing its transmission of motion to the part actuated thereby; and a clutch in said short connection adapted in one position to interrupt its driving action and simultaneously brake the part formerly driven thereby.

15. A feed-change mechanism of the nature disclosed combining a traveling support; a power-driven member; a nut and a screw for transmitting motion from said power-driven member to said support; a positive motion-transmitting connection extending from said member to said nut whereby it may be rotated; a second positive motion-transmitting connection extending from said member to said screw whereby it may be rotated; a series of gears selectively available in one of said connections, to vary the transmitting ratio thereof by predetermined speed increments; means in the last mentioned gear-containing connection for discontinuing its transmission of motion to the part actuated thereby; and a braking-clutch in said other connection adapted in one position to interrupt its driving action and simultaneously brake the part formerly driven thereby.

16. A feed-change mechanism of the nature disclosed combining a traveling support; a power-driven member; two actuated parts the one being a nut and the other being a screw for transmitting motion from said power-driven member to said support; a positive motion-transmitting connection extending from said member to one of said parts whereby it may be actuated; a second positive motion-transmitting connection extending from said member to the other of said parts whereby it may be actuated; a non-braking clutch in one of said connections for discontinuing its transmission of motion to the part actuated thereby; and a braking clutch in said other connection adapted in one position to interrupt its

driving action and simultaneously brake the part formerly driven thereby.

17. In a device of the class described, a carriage, a feed screw journaled thereon, a nut concentric with the screw and journaled against longitudinal travel, driving mechanism for rotating the nut, a screw-driving gear loosely concentric with the screw and journaled against travel, clutch mechanism concentric with the screw and splined thereon adapted to connect said driving gear with the screw in one position and engage with a fixed part to lock said screw against rotation in a second position, driving mechanism for said screw gear, a system of variable speed gearing between said nut and screw driving mechanism, and clutch mechanism for controlling the rotation of said nut.

18. In a device of the class described, a carriage, a feed-screw journaled thereon, a nut concentric with the screw rotatively journaled and held against longitudinal travel, a driving element for rotating the screw, a variable speed system of gearing interposed between the nut and the screw driving element and comprising a series of concentric equal diameter gears with a different number of teeth, and a sliding gear adapted to intermesh selectively with any one of said equal diameter gears, whereby one of said driven elements can be rotated at speeds progressively varying step-by-step from that of the other driven element, and means for controlling the simultaneous or independent rotation of said driven elements for producing a variety of forward or reverse speeds of the carriage.

19. In a device of the class described, a carriage, a feed screw journaled thereon, and movable therewith, a nut rotatively journaled and engaging with the screw, and held against longitudinal travel, a driving element for the screw, a driving element for the nut, and means concentric with the screw adapted to be thrown into operative connection with the driving element therefor for rotating the screw, and into a second position to release the screw from its driving element and lock the same against rotation.

20. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member movable independently of the first; a positive motion-transmission connecting said members whereby they may be caused relatively to rotate at a predetermined normal speed ratio; a speed-change device comprising an organized set of closely graduated gears yielding a crowded series of ratios selectively available in said transmission, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by speed increments each equal to a very small fraction of the predetermined normal speed ratio between said two members; and a part differentially and slowly actuated mutually by said members as they move relatively to one another, whereby the positive speeds at which said part is differentially propelled will be approximately in direct proportion with the corresponding speed increments or multiples thereof, and will each present a large proportional deviation from the speeds nearest it in the series.

21. A feed-change mechanism of the nature disclosed combining a rotatable member; a second rotatable member movable independently of the first; a positive motion-transmission connecting said members whereby they may be caused relatively to rotate at a predetermined normal speed ratio; a speed-change device comprising an organized set of closely graduated gears yielding a crowded series of ratios selectively available in said transmission, whereby the speed of rotation of one member relative to the other may be positively varied step-by-step in progression by speed increments each equal to a very small fraction of the predetermined normal speed ratio between said two members; a part differentially and slowly actuated mutually by said members as they move relatively to one another, whereby the positive speeds at which said part is differentially propelled will be approximately in direct proportion with the corresponding speed increments or multiples thereof, and will each present a large proportional deviation from the speeds nearest it in the series, and means for disconnecting one of said members from said transmission whereby the rotation may be stopped and said part rapidly actuated at fast approximately equal rates each in direct proportion with the sum of one of said increments and said predetermined rate or multiple of said sums.

In testimony whereof, I have hereunto set my hand.

ADOLPH L. DE LEEUW.

Witnesses:
OLIVER B. KAISER,
EMMA SPENER.