

July 5, 1966

A. M. GORFIN

3,258,994

SPEED CHANGING DEVICE

Filed June 3, 1963

5 Sheets-Sheet 1

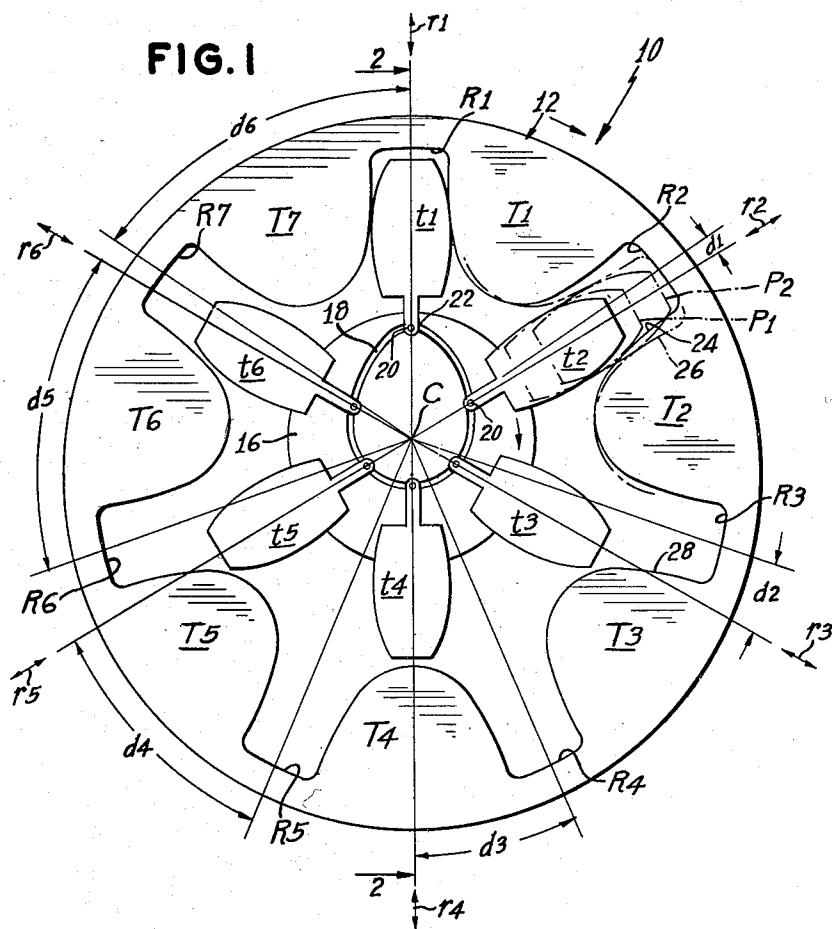
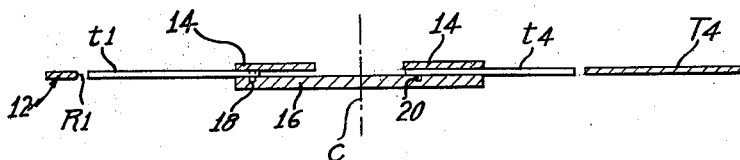


FIG. 2



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5 Sheets-Sheet 2

FIG. 3

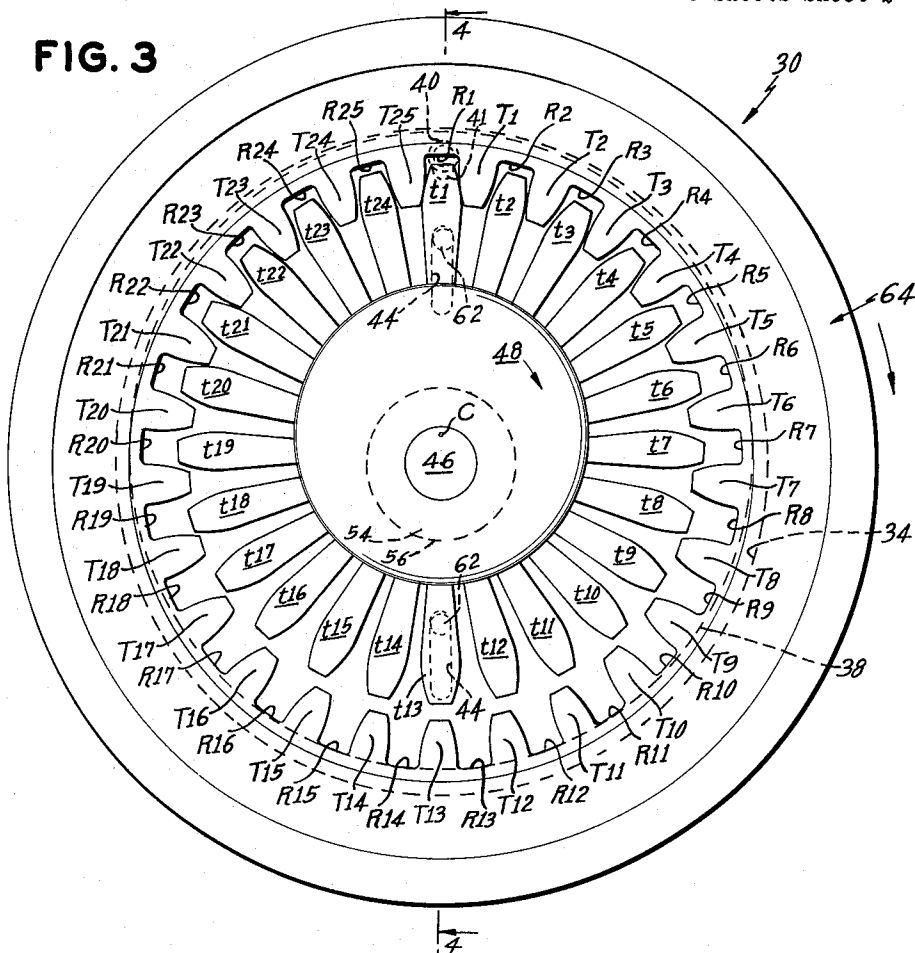
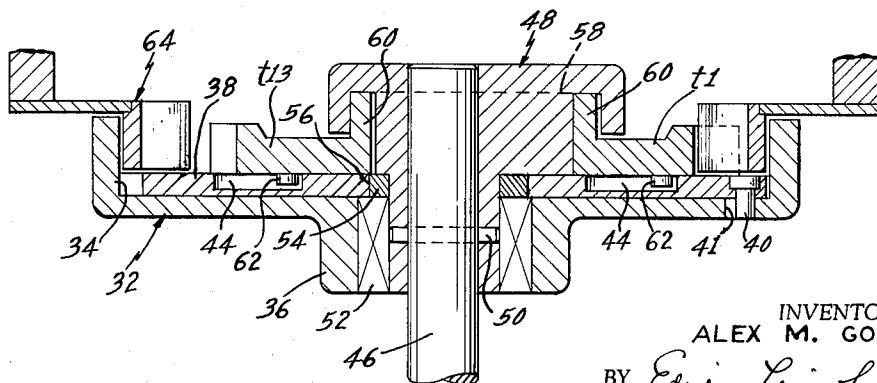


FIG. 4



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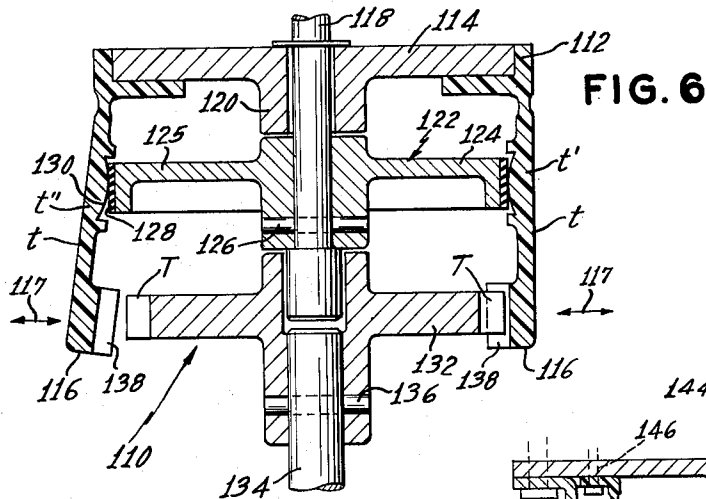


FIG. 7

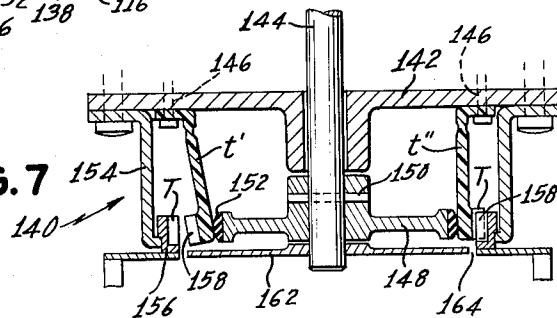
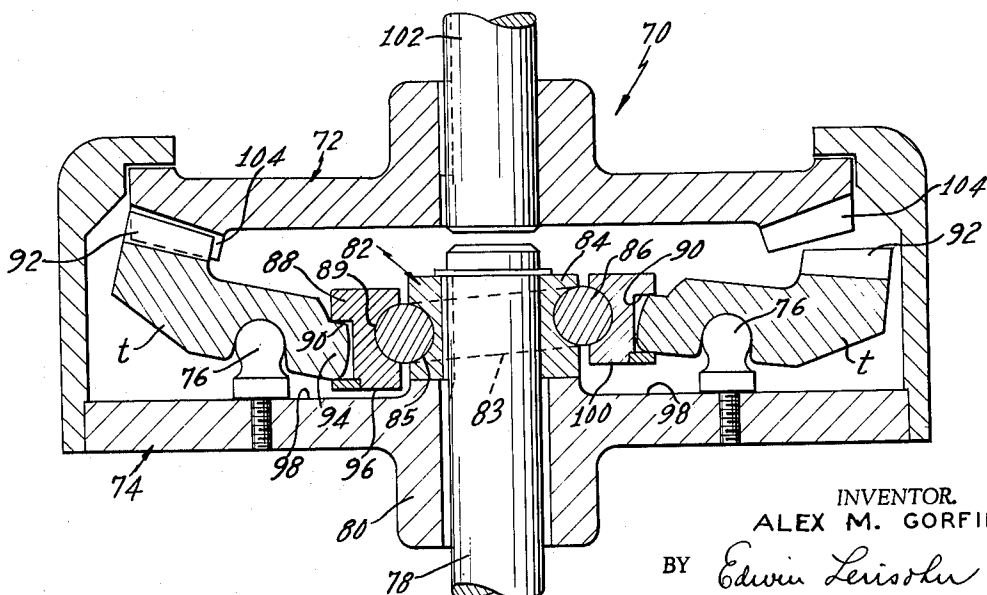


FIG. 5



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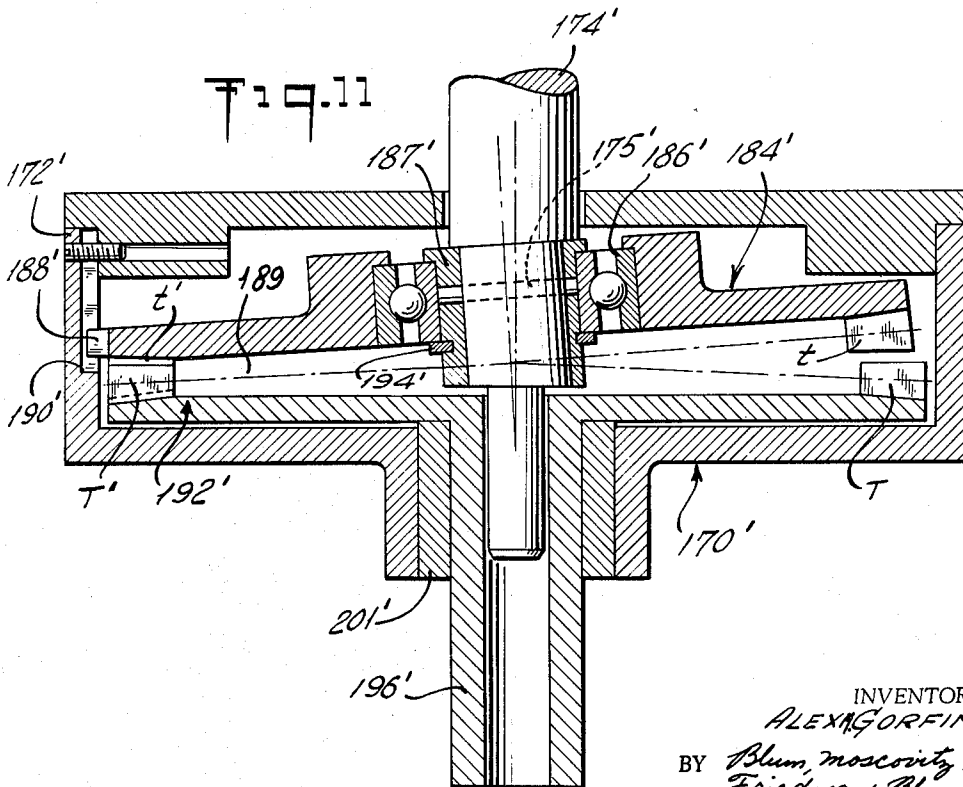
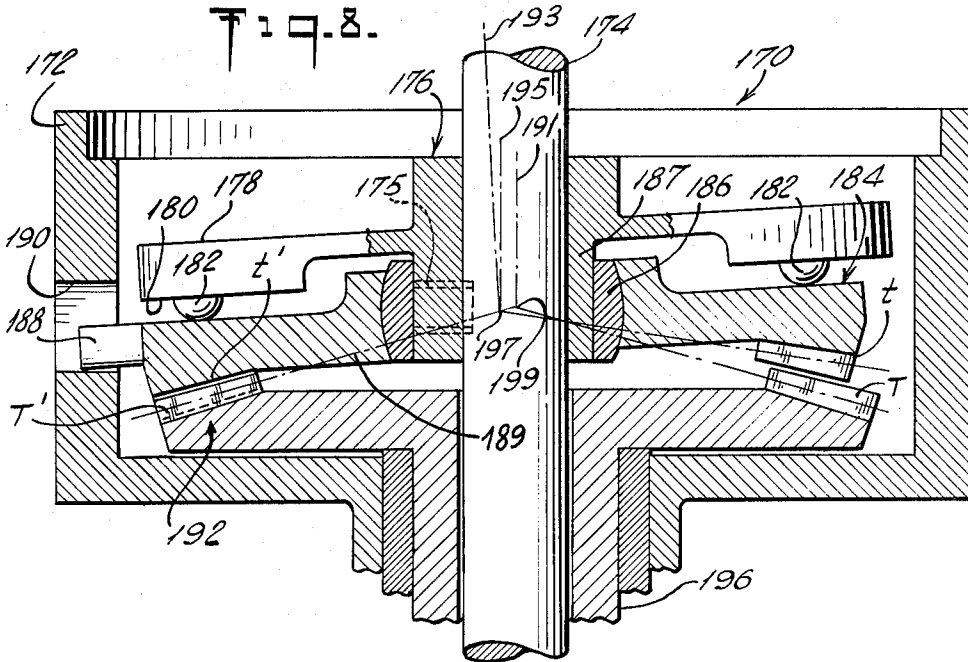
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SPEED CHANGING DEVICE

Filed June 3, 1963

5 Sheets-Sheet 4



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3,258,994

SPEED CHANGING DEVICE

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Filed June 3, 1963, Ser. No. 286,129

13 Claims. (Cl. 74-800)

The present invention relates in general to speed changers and in particular to a rotary speed changer of the gear type for effecting reductions of speed.

This application is a continuation-in-part of my application Serial No. 149,492, filed on October 31, 1961, now abandoned.

Speed reducers of the general type to which the present invention relates are known in the art. However, it has been found that the prior art speed reducers have definite limitations which result in reduced operating efficiency. In particular, it has been found that the ratio of the reduction in speed for a given size device is relatively low and is not as high as desirable. In addition, it has been found that the amount of torque which can be transmitted in the devices of the prior art is quite limited. Moreover, it has also been found that the resulting motion of the driven members is intermittent and not continuous. This presents a great disadvantage.

In view of the foregoing it is an object of the present invention to provide a highly novel and efficient rotary speed changer of the gear type in which there can be achieved a maximum speed reduction.

It is another object of the present invention to provide a speed reducer in which, for a given size device, a greater change or reduction in speed is obtainable than has been possible with prior art devices.

It is another object of the present invention to provide a rotary gear type speed reducer which provides for a relatively large amount of torque transmission.

It is a still further object of the present invention to provide a rotary type gear speed reducer wherein the resulting motion of the driven member is substantially continuous.

It is yet another object of the present invention to provide a speed reducer of the aforementioned type which is extremely compact for a given rating and which provides torque transmission with an efficiency which has hitherto been unobtainable. Pursuant to this object of the present invention there is provided in a unit of the aforementioned type successive progressive full engagement of the complementary gear teeth of the driving and driven members of the unit along a common pitch center which is characteristic of the normal engagement of gear teeth in a conventional train of gears.

Furthermore, the power impulse is secured by power rotation without substantial sliding engagement between the complementary teeth of the driving and driven members.

Other and further objects and advantages of the present invention will be readily apparent to one skilled in the art from a consideration of the following specification taken in connection with the appended drawings.

In the drawings, which illustrate the best mode presently contemplated for carrying out the invention:

FIG. 1 is a more or less diagrammatic or schematic showing of a speed reducer device pursuant to the present invention;

FIG. 2 is a sectional view taken on the line 2-2 of FIG. 1;

FIG. 3 is a plan view of another embodiment of the invention;

FIG. 4 is a sectional view on an enlarged scale taken on the line 4-4 of FIG. 3;

FIG. 5 is a sectional view which illustrates another embodiment of the invention;

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FIG. 6 is a sectional view illustrating an additional embodiment of the invention;

FIG. 7 is a sectional view illustrating a further embodiment of the invention;

FIG. 8 is a sectional view illustrating a still further embodiment of the invention; and

FIG. 9 is an enlarged fragmentary developed view in plan illustrating the gear teeth engagement characteristic of the embodiment of FIG. 8;

FIG. 10 is an enlarged view of the gears shown in FIG. 8 and a side projection thereof further illustrating the manner of gear teeth engagement; and

FIG. 11 is a sectional view illustrating yet another embodiment of the invention of the general type shown in FIGS. 8-10.

Referring now to FIGS. 1 and 2 of the drawing in detail, there is shown a gear assembly 10 which is suitable for many different uses one of which is for use as a speed reducer. The gear assembly 10 is provided with a spur type internal gear 12 which, as here shown, is provided with seven internal teeth T_1 through T_7 , said teeth being defined by seven recesses R_1 through R_7 . It will be understood that the teeth "T" are all similarly dimensioned and that the recesses "R" are likewise all similarly dimensioned. The gear 12 is mounted for rotation in any suitable manner and is adapted to be driven by a plurality of actuating members "t," each of which is similar to a single gear tooth and is adapted to mesh with gear teeth T by entry into the recesses R. These actuating members of teeth are identified in FIG. 1 by the reference numerals t_1 through t_6 . It will be understood that the actuating members t are complementary to the recesses R so that each actuating member may be fully inserted into and withdrawn from an opposing recess R during operation of the speed reduction mechanism 10. Further it will be noted that, as here shown, the number of actuating members t is one less than the number of teeth T, or the number of recesses R, defined in the internal gear 12.

Pursuant to the present invention each of the actuating members t is constrained to move in one direction only, namely a radial direction. More specifically, as shown in FIG. 1, the actuating teeth t_1 - t_6 are disposed about a center point C, being spaced 60° from each other for radial movement relative thereto. Guide or restraining means 14, which may be of any suitable conventional construction, associated with the actuating teeth t, restrain the latter for rectilinear radial movement only. Accordingly, in the position of the parts illustrated in FIG. 1, teeth t_1 and t_4 move only in a vertical direction, which is displaced by 60° from the paths of movement of the adjacent teeth. Arrow-heads r_1 - r_6 associated with the actuating members t_1 through t_6 in FIG. 1, indicate the radial direction of reciprocal rectilinear movements in which the actuating members t_1 through t_6 are constrained for movement. The radial movement of each of the actuating teeth or members t_1 through t_6 is imparted or effected by means of a cam or eccentric means 16 which is provided with a continuous groove 18 defined in a surface thereof. Each actuating tooth t is provided with a laterally extending projecting pin or roller 20 which, as best illustrated in FIG. 2, projects into the groove 18. As here shown, the groove 18 is elliptical in conformation and, accordingly, as the cam 16 is rotated, the groove 18 will move with respect to each projecting pin 20, which is constrained against rotary movement, and cause the latter, as well as the associated actuating member t to move in a radial direction as indicated by the arrow-heads r_1 - r_6 . From the foregoing, it will be readily apparent that rotation of the cam 16 in a clockwise direction, viewing FIG. 1, will cause actuating member t_1 to

move inwardly toward the center point C while causing the adjacent tooth t_2 to move radially outward from the center C since the maximum rise portion 22 in the elliptical conformation of the groove 18 is, in the instantaneous position of the parts shown in FIG. 1, moving from engagement with actuating member t_1 to engagement with actuating member t_2 .

As previously indicated the number of teeth T, or the number of recesses R, of the internal gear 12 exceeds the number of actuating teeth or members t , and, in the present embodiment, the teeth T or recesses R of the internal gear 12 number seven and the actuating teeth t number six. Consequently, in the condition of the parts illustrated in FIG. 1, when the actuating member t_1 is in aligned registry with, and fully engaged or inserted in, the recess R_1 defined between the teeth T_1 and T_7 , none of the other actuating members t are in aligned fully engaged registry with any other recess R of the gear 12. Assuming now that cam 16 begins to rotate in a clockwise direction viewing FIG. 1, it will be apparent that the actuating member t_1 will move radially inwardly toward the center point C while the adjacent actuating member t_2 will move radially outwardly relative to the center C. This, as previously indicated, results from the fact that the maximum rise or cam portion 22 of the groove 18 is moving out of engagement with the pin 20 of the actuating element t_1 toward engagement with the pin 20 of the adjacent actuating element t_2 . During such clockwise rotation of the cam 16, the actuating member t_2 during its outward radial movement moves from the full line position thereof through the broken line position P1 thereof to its maximum outward position shown in broken lines at P2. It will be apparent that during said outward radial movement of the actuating element t_2 , the latter will engage the wall 24 of recess R_2 , which defines the one side edge of the tooth T_2 of the gear 12, such engagement continuing through the various instantaneous positions of the tooth T_2 , as it moves through position P1 to position P2. During said outward radial movement of the actuating element t_2 it will be apparent that, as a result of its engagement with the recess wall 24, there is a force applied to said wall which will impart a clockwise rotational movement or torque to the entire internal gear 12. This force results in a movement of the gear 12 sufficient to move recess R_2 thereof from its full line position to the broken line position thereof indicated by the reference numeral 26. At this point, the actuating member t_2 is in registered alignment with and fully inserted or engaged in the recess R_2 in the same manner as that shown by the actuating member t_1 with relation to the recess R_1 in FIG. 1. It will be understood that the various elements, namely the teeth T, the recesses R, the actuating members t and the cam groove 18 are so related and relatively conformed in shape that sufficient withdrawal of the actuating member t_1 is effected so as to provide sufficient clearance to permit the internal gear 12 to rotate in response to outward radial movement of the actuating element t_2 and the similar movement of the succeeding actuating elements.

Consequently, it will be readily apparent that rotation of the cam 16 by 60° has caused the internal gear 12 to move through an angular distance indicated by the reference d_1 in FIG. 1. Continued clockwise rotation of the cam 16 will, in a similar manner to that described above, cause the actuating member t_2 to move radially inwardly toward the center C while the adjacent actuating member t_3 moves radially outwardly from center C to engage with the wall 28 of the recess R_3 , which defines one side edge of the tooth T_3 so as to cause an additional rotation of the gear 12 for another increment of distance d_1 . Therefore, it will be readily apparent that after the cam 16 has rotated through 120° of movement thereof, the internal gear 12 will have been rotated an angular distance equal to d_2 . Continued rotation of the cam 16 in the same clockwise direction will provide for the progressive

successive engagement of the successive actuating elements t into aligned registry with, and full insertion into, the successive recesses R so that each of said successive actuating elements t provides for an additional angular or rotary movement d_1 of the internal gear 12. Therefore it will be apparent that, for a complete rotation of the cam 16 through 360° thereof, the internal gear 12 will be moved a distance d_6 which is equivalent to six times the distance d_1 . Therefore, it will be apparent that cam 16 may constitute the driving means for the assembly 10, it being understood that the cam can be mounted and driven in any suitable conventional manner.

From the foregoing it will be apparent that the extent of angular rotation of the internal gear 12 for each revolution of the cam 16 is a function of the number of teeth T (or recesses R), the number of actuating members t , and the difference between the two. In this relationship it will be apparent that the number of teeth T may be substituted for the number of recesses R since they are both equal so that it will be understood that in the following consideration of the relationships of the various parts, the teeth T may be substituted for the recesses R. More specifically, the ratio of the angular velocity of the internal gear 12 to the angular velocity of the cam 16 is equal to the difference between the number of teeth T and the number of actuating members t divided by the number of teeth T to provide the following equation:

$$W_{12}/W_{16} = NT - Nt/NT$$

wherein 12 is representative of the internal gear and 16 is representative of the cam.

The described gear assembly 10 may be advantageously used as a speed reducer instead of using it as a normal gear reduction train. For example, if the cam 16 constitutes the driving member and the internal gear 12 constitutes the driven member a very high speed reduction can be obtained in accordance with the described operation. For example, if a 100:1 speed reduction is desired, the internal gear 12 would have 100 teeth T while the cam 16 would operate 99 actuating members t , and the internal gear 12 would have an angular speed equal to $1/100$ of the angular speed of the cam 16. This arrangement for obtaining a 100:1 speed reduction has many advantages which are not presently available with conventional speed reduction gear assemblies. It will be understood that the angular rotation of the internal gear 12 can be used in turn to drive another member, or could be used to actuate indicators in high precision instruments. Further it will be understood that any suitable conventional mechanism may be used to drive the cam 16 and that any suitable conventional mechanism may be used to mount the internal gear 12 for the described rotation and for operatively connecting the gear 12 to another element or part to which the described reduced speed is to be transmitted. Further, it will be apparent that the difference in number between teeth T and teeth t may be other than one.

Referring now to FIGS. 3 and 4, of the drawings, in detail, there is shown another embodiment of the invention. In FIGS. 1 and 2 the actuating elements t were mounted for radial reciprocity by the previously described eccentric groove 18 provided in the centrally mounted regular cam 16. In the present embodiment the arrangement is such that in lieu of the eccentric groove provided in a centrally mounted cam, provision is made for an eccentric cam means constituted by a cam which itself is eccentrically mounted. More specifically, the rotary gear speed reducing assembly 30 of the present embodiment comprises a housing or bearing member 32 which, as here shown, is internally dished, as at 34, and provided with a hub portion 36. A circular guide plate 38, which conforms to the dished conformation 34 of the bearing member 32 but which has a diameter smaller than the internal diameter of the dished portion 34, is mounted for limited movement relative to the dished surface of hous-

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ing 32 by means of the pin 40 mounted in a radial slot 41 in said housing 32. The guide plate 38 is provided with a plurality of radial guide slots 44. Provision is made for a drive shaft 46, to which there is fixed an eccentric or cam means 48, as at 50. As here shown, cam means 48 is a circular member which is mounted eccentrically on the shaft. The shaft and cam member 48 are mounted in the hub 36 of the bearing member 32 for rotation relative thereto, provision being made for a suitable anti-friction mounting 52 therefor. The cam member 48 is provided with a collar 54 which extends through a central aperture 56 provided in the guide plate 38. The cam or eccentric 48 is provided with a circular groove 58, which is defined therein. Provision is made for a plurality of individual actuating elements t , each of which is provided with a tail portion 60 which is seated within the groove 58. The actuating elements t are each provided with a laterally projecting pin portion 62 which extends into a companion elongated guide slot 44. It will be understood that guide slots 44 are equal in number to the actuating elements t and that each guide slot receives the pin 62 of the associated actuating element so as to constrain the latter against rotary movement and to allow only for radial reciprocation relative to the center of the cam member 48. An internal gear member 64 is mounted in a suitable conventional fashion relative to the bearing member 32 for cooperation of the actuating elements t with the gear 64, in the manner hereinafter described. As here shown, the internal gear 64 is provided with twenty-five internally extending gear teeth identified by the reference numerals T_1 through T_{25} which are defined by twenty-five gear recesses R_1 and R_{25} . It will be noted from each of FIGS. 3 and 4 that the cam member 48, which is of circular configuration and which is provided with the circular groove 58, is mounted in an eccentric manner on the drive shaft 46. The groove 58 mounts twenty-four actuating members or teeth indicated by the reference numerals t_1 through t_{24} to cooperate with the gear teeth T and the gear recesses R , it being noted that there is one less in the number of actuating elements t than in the number of gear teeth T or gear recesses R . It will also be noted that in the present embodiment, the guide plate 38 is provided with twenty-four guide slots 44 each of which restrains one of the actuating members t for radial reciprocation relative to the center point C of the cam or eccentric 48. Further it will be understood that the various actuating members t are dimensioned and shaped so as to be complementary to the dimensions and shapes of the gear teeth T and the gear recesses R .

The embodiment, illustrated in FIGS. 3 and 4, operates in the same manner as the embodiment illustrated in FIGS. 1 and 2. More specifically, the rotation of the eccentric or cam member 48 by the drive shaft 46 will cause the radial rectilinear reciprocations of the various actuating members or teeth t into and out of registered fully inserted alignment within the recesses R of the gear member 64. For example, as shown in FIG. 3, the actuating member t_1 is fully engaged in aligned registration with the recess R_1 of gear member 64. Rotational movement of the eccentric 48 in a clockwise direction viewing FIG. 3, will cause the adjacent actuating element t_2 to move fully radially outwardly into full insertion in the recess R_2 so as to impart an angular movement in a clockwise direction to the internal gear 64, in the same manner as previously described in connection with FIG. 1, it being understood that as the successive actuating elements t move progressively into engagement with the successive recesses R , a similar angular rotary movement is imparted to gear 64. If, as in the prior embodiment, the angular movement of the internal gear 64 effected by each of the actuating members t , is equal to a distance d_1 , it will be apparent that in the described embodiment one complete rotation through 360° of the eccentric or cam 48 will result in a rotary movement of the gear 64 which is equal to d_1 multiplied

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by 24 since there are 24 actuating elements which operate in response to the eccentric 48.

Referring now to FIG. 5 of the drawing, in detail, there is shown, a gear assembly 70 which differs from the previously described speed reducer assemblies in that a bevel gear 72 is utilized as the driven member, in lieu of the internal gear members described in the prior embodiments. As here shown, provision is made for a dished bearing or housing member 74 which mounts a plurality of bevel toothed actuating members t . Each actuating member t is mounted for pivotal movement on a pivot pin or member 76 provided in housing 74. It will be understood that each pivot member 76 restrains its associated actuating member t against any movement except a pivotal movement, as hereinafter described in detail, so that said members t are restrained from rotary movement. A drive shaft 78, journaled in hub 80, extends therethrough and mounts an eccentric or cam means, which is generally indicated by the reference numeral 82, for rotation with the drive shaft. More specifically, the eccentric or cam means 82 comprises a collar 84, which is keyed to the drive shaft 78, and which is provided with a peripheral continuous cam groove 85 which is disposed eccentrically relative to the axis of the drive shaft 78. More specifically, and as here shown, the diameter of the annular groove 85 is not normal to, or at right angles relative to, the axis of the shaft 78 but is disposed at an angle thereto which is other than a right angle so that the right hand portion of the annular groove 85, viewing FIG. 5, is displaced vertically upwardly from the diametrically opposed left hand portion of said annular groove. Annular groove 85 constitutes one half or a raceway, 83, for balls or rollers 86. The other half of said raceway 83 is defined by an internal continuous peripheral groove 89 on a collar 88, through which collar 88 previously mentioned collar 84 extends. Each actuating element t is provided at one end thereof with a beveled tooth 92 and at the other end thereof with a tail 94 which is disposed within a groove 90 provided on the external periphery of collar 88. It will be apparent that, as the eccentric means 82 is rotated by the drive shaft 78, the rotating balls 86 will cause a portion 96 of collar 88 to approach the adjacent surface 98 of the housing 74, while the diametrically opposed portion 100 thereof moves away from the housing surface 98. In other words, in addition to rotation with the shaft 78, the collar 88 of the eccentric or cam means 82 will rock toward and away from the housing face or surface 98. Said rocking movement of the collar 88 of cam means 82 during the rotation of the latter will result in the pivotal movement of each actuating element t about its pivot 76 so that the beveled tooth 92 thereof will rock toward and away from the surface 98 of the housing 74. While the coupling between the collar 84 and the grooved collar 88 has been illustrated and described as being constituted by ball bearings disposed within an eccentrically mounted annular member 82 it will be understood that it is within the scope of the present invention to utilize other forms of couplings suitable for the purpose.

The speed reducing assembly 70 is provided with the previously described beveled gear member 72 which, as here shown, is keyed to an output shaft 102. The beveled gear 72 is provided with suitable beveled teeth 104 which are adapted to mesh with the previously mentioned teeth 92 of the actuating elements t . It will be understood that the number of actuating elements t is less than the number of beveled gear teeth 104, for example, the difference may be one. Consequently, it will be understood that the pivotal movement of each actuating element t toward and away from engagement with an opposing beveled tooth 104 of the beveled gear 72, said engagement occurring in a successive progressive manner, will result in the same action as that described in the prior embodiments. In this connection it will be understood that the beveled teeth 104 are the equivalent of the teeth T of the spur gears in the previously described embodiments so that the meshing

of the actuating elements *t* with said beveled teeth 104 will result in angular rotary movements of the beveled gear 72. In other words, the successive rectilinear reciprocal movement of actuating elements *t*, in response to the rotation of cam means 82, will cause the meshing of said elements *t* with the beveled teeth 104 to, in turn, impart to beveled gear 72 a rotary movement. The ratio of the angular velocity of the beveled gear 72 to the angular velocity of the eccentric or cam means 82 may be determined by applying the previously explained formula. More specifically, and by way of example, if the difference between the number of teeth 104 and the number of actuating elements *t* is one, then for each complete revolution of cam means 82 bevel gear 72 will have been rotated an angular distance of 360° divided by the number of teeth 104.

Referring now to FIG. 6 in detail, there is described another embodiment of a speed reducer pursuant to the present invention. The speed reducer 110 of the present embodiment is similar to that disclosed in FIGS. 1 and 3 in that the meshing gears thereof are of the spur gear type. The driven member, in accordance with this embodiment comprises an ordinary spur gear 132 having external teeth T, which gear 132 is secured to shaft 134 by pin 136. The driving or actuating members *t* are fixed at one end thereof, as at 112, to a mounting disk 114.

In the present embodiment the actuating members *t* are formed of a suitable resilient or yieldable material, for example a suitable resilient plastic or spring metal, so that although they are fixed at the ends 112 thereof, it will be understood that the free ends 116 are capable of reciprocation in a radial direction, as indicated by arrows 117, relative to the center of the mounting member 114. As here shown, a drive shaft 118 extends through the hub portion 120 of the mounting member 114 and mounts an eccentric disk or drive member 122 thereon. The driving disk 122 is an eccentrically mounted circular member, it being noted that in FIG. 6 the right hand portion 124 thereof is smaller than the left hand portion 125 thereof. Said eccentric driving disk or cam means 122 is keyed to the driving shaft 118, as at 126. The eccentric 122 is provided with a peripheral bearing surface 128 which engages with a complementary bearing portion 130 provided on each of the actuating members *t* so as to effect the radial movements of the latter to and from the fully relaxed position thereof as shown at *t'* at the right hand side of FIG. 6 and the fully biased position thereof as shown at *t''* in the left hand portion of FIG. 6. Each actuating member *t* is provided at the free end thereof with a tooth 138, complementary to teeth T on the driven spur gear 132. Obviously, as in the other embodiments, there is a difference between the number of teeth T and actuating elements *t*. Accordingly, as eccentric 122 is rotated, it will cause each actuating element *t* to reciprocally move between the fully relaxed positions (as *t'*) in which it is snugly in engagement with a tooth T to a fully biased position (as *t''*) in which it is furthest away from teeth T. In view of the difference in number between teeth T and actuating elements *t*, the reciprocal movement of the latter will impart to teeth T, and thus to gear 132, purely rotational movement. Thus it is seen that the operation of this embodiment is similar to that of the previous embodiments and that the ratio between the angular velocity of the driven member 132 and that of the driving member (eccentric 122) can be determined by applying the previously described formula.

Referring now to FIG. 7 in detail, there is shown an additional embodiment which utilizes an external spur gear as the driven member. As here shown, the speed reducing mechanism 140 is provided with a stationary support member 142 to which a plurality of actuating members *t* are mounted by bolts 146, at the under surface thereof, being arranged in circular relationship to each other. Said actuating elements *t* are formed of a suit-

able resilient or spring material, the relaxed or unbiased condition thereof being indicated at the left hand side of FIG. 7, at *t'*, the biased condition thereof being indicated at the right hand side at *t''*. A drive shaft 144 extends through the support member 142. The drive shaft 144 mounts a rotary eccentric 148 constituted by a circular member which is eccentrically mounted on the shaft 144, as at 150. The eccentric cam member or drive member 148 is similar to the previously described eccentric or cam member 122 of FIG. 6 and is provided also with a peripheral bearing surface 152 which engages with the actuating members *t* so as to effect radial reciprocations of the latter to and from the relaxed condition thereof shown by the element *t'* and the biased condition thereof shown by the element *t''*. The supporting member 142 also mounts a circular guide 154, as at 156. The guide 154 slidably supports a spur gear 156 provided with the external teeth T, it being understood that the spur gear 156 is free to rotate relative to the guide 154. The actuating elements *t* are provided at their free ends with teeth 158 which are complementary to the teeth T of the gear 156 and are adapted to mesh therewith. As in all previous embodiments the number of elements *t* is different from the number of teeth T. The embodiment illustrated in FIG. 7 operates in the same manner as the previously described embodiments which utilize spur gears, namely FIGS. 1, 3 and 6. More specifically, the rotation of the drive or cam member 148 results in the actuation of the drive or actuating members *t* from the positions thereof out of engagement with the teeth T of the spur gear 156 into engagement with the latter as in the right hand portion of FIG. 7. This results in applying a force to the external gear 156 in the same manner as previously described so as to provide the latter with an angular rotary movement, it being understood that the teeth *t* successively progressively mesh with the gear teeth, T. It will be understood that as in the prior embodiments the number of teeth T on the gear 156 exceeds by at least one the number of actuating elements *t* and the operation proceeds in the same manner as previously described. The ratio of the angular velocity of the external gear 156 to the angular velocity of the cam 148 may be determined by applying the previously explained formula. A cover member 162 may be provided within the central opening 164 provided in the gear 156 and serves as a bearing for the drive shaft 144.

It will be understood that it is within the scope of the present invention to utilize a toothed rack, in lieu of spur gear 156, provided with the teeth T, and arrange the actuating teeth *t* to successively and progressively mesh with the teeth T of the rack to move the latter in a rectilinear direction.

Referring now to FIGS. 8-10 in detail, there is shown another embodiment 170 utilizing a bevel gear in lieu of a spur gear.

Pursuant to the present embodiment provision is made for a housing 172 which mounts a rotary drive shaft 174. An eccentric or cam means 176 is keyed to shaft 174 as indicated at 175 for rotation thereby. In the present embodiment the eccentric or cam means 176 is constituted by a circular member or disk 178 which is mounted on the drive shaft 174 in such a manner that the diameter of the disk 178 intersects the axis of the shaft 174 at an oblique angle or at an angle other than a right angle. Consequently, as here shown, the member 178 does not rotate in a plane which is normal to the axis of shaft 174 but rotates in a plane which is other than normal relative thereto so that it is effectively in a plane obliquely eccentric to the axis of shaft 174, as will be more fully explained below. More specifically, as in the position of the parts shown in this figure, the right hand portion of the disk 178 is displaced upwardly from the left hand diametrically opposed portion thereof. The disk 178 is provided at its under surface 180 with pressure balls 182 which are free to rotate therein and

which are retained therein against movement along the surface of the disk 178. Provision is made for a first beveled gear 184 which is mounted within the housing 172 by a bearing mounting means 186 which permits the gear 184 to rock about an eccentric axis. The gear 184 is retained against rotation relative to the shaft 174 by means of a projection 188 thereof which extends into an elongated guideway or slot 190 provided in the housing 172. Provision is made for a second beveled gear 192 which is disposed within the housing 172. The gear 184 is provided with beveled teeth *t* which constitute actuating elements adapted to engage or mesh with the complementary beveled teeth *T* provided on the gear 192. It will be understood that as in each of the prior embodiments the number of teeth *T* on the gear 192 exceeds by at least one the number of teeth or actuating elements *t* provided on the gear 184. Therefore, it will be apparent that as the eccentric means 178 is rotated by the shaft 174 the pressure balls 182 provided thereon effect a rocking movement of the first beveled gear 184 so as to successively progressively effect the engagement of the teeth *t* thereon with the teeth *T* of the gear 192. It will be noted that the complementary teeth *t* and *T* at the diametrically opposed right hand portion of the figure are out of engagement. In view of the foregoing, it will be understood that the operation is the same as in the previously described embodiments, the meshing of each actuating tooth *t* with each of the complementary teeth *T* on gear 192 resulting in an angular displacement of the gear 192, as previously described, to continuously rotate the latter. The ratio of the angular velocity of the bevel gear 192 to the angular velocity of the cam means 176 is equal to the difference between the number of teeth *T* provided on the gear 192 and the actuating members *t* provided on the gear 184 divided by the number of teeth *T* in the manner previously described.

More specifically, if for example, beveled gear 192 is provided with 100 teeth *T*, while bevel gear 184 is provided with 99 teeth *t*, then for every complete revolution of the driving member or cam means 176, there would be a resulting angular movement of the driven member, gear 192, of $\frac{1}{100}$ of a revolution. The output of the driven member could be transmitted wherever desired by any conventional means, such as through shaft 196 of the driven member as shown in FIG. 8.

While the principle of operation of the embodiment shown in FIGS. 8-10 is similar to that of the other embodiments, in that the driving member is restrained from any rotational movement, but merely has its teeth *t* successively and progressively engage and disengage the teeth *T* of the driven member, with such driving teeth *t* moving solely in a reciprocable manner, to accomplish the tremendous reduction in speed for a given size device, nevertheless, the embodiment of FIGS. 8-10 is different from the other embodiments in that the actuating member constitutes a gear having the teeth *t* thereof unitary with the gear and fixed thereto. In other words, the individual driving teeth *t* are not movable with respect to gear 184, but are, as teeth in any beveled gear, movable only in unison with every other part of gear 184. This is best shown in FIGS. 9 and 10 where it is quite clear that teeth *t* constitute ordinary teeth of beveled gear 184.

The motion imparted to the gear 184 is the composite of the rocking motion effected by disk or wobble plate 178 and eccentric motion achieved by eccentric collar 187 of cam means 176, it being noted that such composite motion results in the gear teeth *t* or *T* being progressively fully engaged along the common pitch center line 189 of the gears 184 and 192. Thus, the composite motion provides between the gear teeth *t* and *T* a relative movement not only in depth (from the tips to the roots of the teeth) but also longitudinally. In the instantaneous position illustrated in FIGS. 8-10, the gear teeth *t'* and *T'* are shown fully engaged along the pitch lines of their

respective gears in the manner of the gear teeth of a conventional gear train, and each pair of companion teeth are progressively so fully engaged in a continuous manner by the composite rocking and eccentric motion imparted to the driving gear 184. This assures a power impulse secured by pure rotation without sliding engagement between the teeth *T* and *t*. In the instantaneous position shown, the axis of rotation of the gear 192 and shaft 174 is indicated at 191 while the axis of gear 184 is indicated at 193, said axes being at right angles to their respective gears. The center line of the collar 187 of the wobble plate or disk 178 is indicated at 195 and the lateral spacing between lines 191 and 195 corresponds to the eccentricity of the gear 184.

It will be noted that the centers 197 and 199, of the gears 184 and 192, respectively lie along the common pitch line 189 and this condition continuously and progressively takes place for each companion pair of teeth as the shaft 174 rotates to impart the composite movement aforementioned to the driving gear.

As shown in FIG. 9 all contact between adjacent gear teeth takes place on the pitch circle of the driving gear which is coincident with the pitch circle of the driven gear when the teeth are fully engaged as shown at *T'*, *t'*. As clearly shown in FIG. 10, the gear 192 is of somewhat larger diameter than gear 184 due to difference in number of teeth but full engagement of each companion pair of teeth is progressively achieved by the geometry of the composite rocking and eccentric action applied to the driving gear. The maximum lateral displacement 200 at the diametric opposite side of the fully engaged teeth is equal to twice the eccentricity of collar 187. This arrangement provides a very efficient speed reduction unit which is capable of transmitting very high torque. In the specific embodiment shown, gear 184 is provided with 24 teeth while gear 192 is provided with 25 teeth.

If desired, the speed reducing unit may achieve the aforementioned results with the elimination of the wobble plate 178. More particularly and with reference to FIG. 11, there is shown another embodiment 170' which differs from embodiment 170 by the elimination of the wobble plate 178. In embodiment 170' the gear 184' has the same composite motion as gear 184 and this composite motion is achieved by eccentrically mounting gear 184' for rocking reciprocation about an axis oblique to the axis of shaft 174'. The eccentric collar 187' is pinned to shaft 174' as indicated at 175' and surrounding said collar is a ball bearing assembly 186' which is assembled to the collar 187' by a snap ring 194'. The bearing assembly 186' mounts the gear 184' which is retained against rotation in the aforescribed manner and rocks in an eccentric path describing the same movement imparted by gear 184 of the previous embodiment to progressively and continuously engage the companion teeth of gear 192' to drive the latter. The gear 192' may be conventionally coupled to any power unit by means of shaft 196' mounted in bearing 201', or in any suitable manner. It will be understood that the outer race of bearing assembly 186' is press fitted in gear 184' and is stationary therewith, the balls of the bearing assembly transmitting the eccentric rotation of collar 187' to said gear. In all other respects the embodiment 170' corresponds to embodiment 170 and the gear teeth engagement and geometry thereof illustrated in detail in FIGS. 9 and 10 are similarly equally applicable to embodiment 170'.

While I have shown and described the preferred embodiments of my invention, it will be understood that the invention may be embodied otherwise than as herein specifically illustrated or described, and that in the illustrated embodiment certain changes in the details of construction and in the form and arrangement of parts may be made without departing from the underlying idea or principles of this invention within the scope of the appended claims.

What is claimed is:

1. A rotary speed changer comprising rotary spur gear means provided with external gear teeth, a plurality of actuating elements individually mounted only for radial reciprocation into engagement with and disengagement from said gear teeth, the number of gear teeth differing from the number of actuating elements, and rotary eccentric means operable on said actuating elements to effect the successive progressive engagement and disengagement of said actuating elements and said gear teeth, said actuating elements constituting resilient members secured at one end thereof and having a free end disposed to normally engage the gear teeth, and said rotary eccentric means being operable to urge the free end thereof out of said engagement.

2. A rotary speed changer comprising rotary spur gear means provided with external gear teeth, a plurality of actuating elements individually mounted only for radial reciprocation into engagement with and disengagement from said gear teeth, the number of gear teeth differing from the number of actuating elements, and rotary eccentric means operable on said actuating elements to effect the successive progressive engagement and disengagement of said actuating elements and said gear teeth, said actuating elements constituting resilient members secured at one end thereof and having a free end disposed to normally disengage the gear teeth, and said rotary eccentric means being operable to urge the free end thereof into engagement with said gear teeth.

3. A rotary speed changer comprising rotary gear means provided with beveled teeth, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means mounting said actuating means against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary teeth, and rotary eccentric means operable on said actuating means to effect said composite motion and successive progressive engagement and disengagement of said complementary teeth and said gear teeth.

4. A rotary speed changer as in claim 3, wherein the number of gear teeth exceeds by one the number of complementary teeth.

5. A rotary speed changer comprising a rotary gear means provided with beveled teeth, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means mounting said actuating means against rotary movement and for the reciprocable movement of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of said gear teeth differing from the number of said complementary teeth, and rotary eccentric means operable on said actuating means to effect successive progressive engagement and disengagement of said complementary teeth and said gear teeth by movement of said complementary teeth in substantially planar paths for substantially full play-free engagement with said gear teeth, said actuating means comprising actuating elements each individually mounted for pivotal movement to effect said engagement and disengagement of a complementary tooth and a gear tooth.

6. A rotary speed changer comprising a central drive-shaft, rotary gear means provided with beveled teeth mounted for rotation on said shaft, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means eccentrically mounting said actuating means on said drive shaft against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary teeth, and rotary eccentric means operable on said actuating means to effect said composite motion

and successive progressive engagement and disengagement of said complementary teeth and said gear teeth, said actuating means comprising a beveled gear constrained against rotary movement and mounted for reciprocable rocking movement in an eccentric path relative to the axis of rotation of said rotary gear means to effect said engagement of said complementary teeth and said gear teeth, and said eccentric means being rotatable on said shaft in a plane obliquely related to said axis of rotation.

7. A rotary speed changer comprising rotary gear means provided with beveled teeth, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means eccentrically mounting said actuating means against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary teeth, and rotary eccentric means operable on said actuating means to effect said composite motion and successive progressive engagement and disengagement of said complementary teeth and said gear teeth, said actuating means comprising a beveled gear constrained against rotary movement and mounted for reciprocable rocking movement in an eccentric path relative to the axis of rotation of said rotary gear means to effect said engagement of said complementary teeth and said gear teeth, and said eccentric means being rotatable in a plane obliquely related to said axis of rotation, said eccentric means comprising a disc overlying said actuating means for rotation in said oblique plane and balls operable by said disc in a constrained path on the underlying surface of said disc for rocking said beveled gear in said eccentric path, said disc, actuating means and rotary gear means having a common driveshaft extending therethrough and defining said axis of rotation with said disc and rotary gear means being rotatable thereon.

8. A rotary speed changer comprising rotary gear means provided with beveled teeth, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means eccentrically mounting said actuating means against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary teeth, and rotary eccentric means operable on said actuating means to effect said composite motion successive progressive engagement and disengagement of said complementary teeth and said gear teeth, said actuating means comprising a beveled gear constrained against rotary movement and mounted for reciprocable rocking and eccentric movement in an eccentric path relative to the axis of rotation of said rotary gear means to effect said engagement of said complementary teeth and said gear teeth, and said eccentric means being rotatable in a plane obliquely related to said axis of rotation, said gear teeth being progressively fully engaged along a common pitch center line of said beveled gear and gear means.

9. A rotary speed changer comprising rotary gear means provided with beveled teeth, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means eccentrically mounting said actuating means against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary teeth, and rotary eccentric means operable on said actuating means to effect said composite motion and successive progressive engagement and disengagement of said complementary teeth and said gear teeth, said actuating means comprising a beveled gear constrained against

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rotary movement and mounted for reciprocable rocking and eccentric movement in an eccentric path relative to the axis of rotation of said rotary gear means to effect said engagement of said complementary teeth and said gear teeth, and said eccentric means being rotatable in a plane obliquely related to said axis of rotation, said eccentric means comprising a disc overlying said actuating means for rotation in said oblique plane and balls operable by said disc in a constrained path on the underlying surface of said disc for rocking said beveled gear in said eccentric path, said gear teeth being progressively fully engaged along a common pitch center line of said beveled gear and gear means.

10. A rotary speed changer comprising, toothed rotary gear means adapted to be rotated about an axis of revolution, toothed actuating means adapted to mesh with said gear means for rotating the latter, the number of teeth on said gear means exceeding by one the number of teeth on said actuating means, the teeth of said actuating means being restrained against rotational movement about said axis and being movable only into and out of engagement with the gear teeth, and rotary eccentric means operable on said actuating means to effect the successive progressive full engagement and disengagement of the actuating teeth and the gear teeth along a common pitch center line of said gear means and actuating means, said rotary eccentric means providing movement of said teeth of said actuating means relative to said gear teeth both in depth and longitudinally.

11. A rotary speed changer comprising a central drive-shaft, rotary gear means provided with beveled teeth mounted for rotation on said shaft, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means eccentrically mounting said actuating means on said shaft against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary teeth, said actuating means comprising a beveled gear constrained against rotary movement and mounted for reciprocable rocking eccentric movement in an eccentric path relative to the axis of rotation of said rotary gear means to effect said engagement of said complementary teeth and said gear teeth, and said beveled gear being disposed for said rocking movement in a plane obliquely related to said axis of rotation, and rotary eccentric means operable on said actuating means to provide movement of the teeth thereof relative to said gear teeth both in depth and longitudinally.

12. A rotary speed changer comprising a central drive-shaft, rotary gear means provided with beveled teeth mounted for rotation on said shaft, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means eccentrically mounting said actuating means on said shaft against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary

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teeth, said actuating means comprising a beveled gear constrained against rotary movement and mounted for reciprocable rocking and eccentric movement in an eccentric path relative to the axis of rotation of said rotary gear means to effect said engagement of said complementary teeth and said gear teeth, and said beveled gear being disposed for said rocking movement in a plane obliquely related to said axis of rotation, said gear teeth being progressively fully engaged along a common pitch center line of said beveled gear and gear means, the centers of rotation of said beveled gear and gear means in the fully engaged condition of the gear teeth thereof being spaced from each other and disposed substantially along said pitch center line.

13. A rotary speed changer comprising a central drive-shaft, rotary gear means provided with beveled teeth mounted for rotation on said shaft, actuating means provided with complementary beveled teeth for engagement with said gear teeth, means eccentrically mounting said actuating means on said shaft against rotary movement and for composite rocking and eccentric motion of said complementary teeth to effect said engagement and for disengagement with said gear teeth, the number of gear teeth differing from the number of said complementary teeth, and rotary eccentric means operable on said actuating means to effect successive progressive engagement and disengagement of said complementary teeth and said gear teeth, said rotary eccentric means providing movement of said teeth of said actuating means relative to said gear teeth both in depth and longitudinally, and said actuating means comprising a beveled gear constrained against rotary movement and mounted for reciprocable rocking and eccentric movement in an eccentric path relative to the axis of rotation of said rotary gear means to effect said engagement of said complementary teeth and said gear teeth, and said eccentric means being rotatable on said shaft in a plane obliquely related to said axis of rotation, said gear teeth being progressively fully engaged along a common pitch center line of said beveled gear and gear means, the center of rotation of said beveled gear and the center of rotation of said gear means in the fully engaged condition of the gear teeth thereof being spaced from each other and disposed substantially along said pitch center line.

References Cited by the Examiner

UNITED STATES PATENTS

871,240	11/1907	Schoedelin	74—800
1,543,791	6/1925	Pitter	74—801 X
1,743,844	1/1930	Black	74—63
2,134,603	10/1938	Crosman	74—122
2,508,121	5/1950	McIver	74—805 X

FOREIGN PATENTS

174,873	2/1922	Great Britain.
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