No. 745,952. PATENTED DEC. 1, 1903.

J. H. BARNARD.

APPARATUS FOR TRANSMITTING POWER.

APPLICATION FILED MAR. 8, 1902.

NO MODEL. 2 SHEETS—SHEET 1.

Fig. 1.

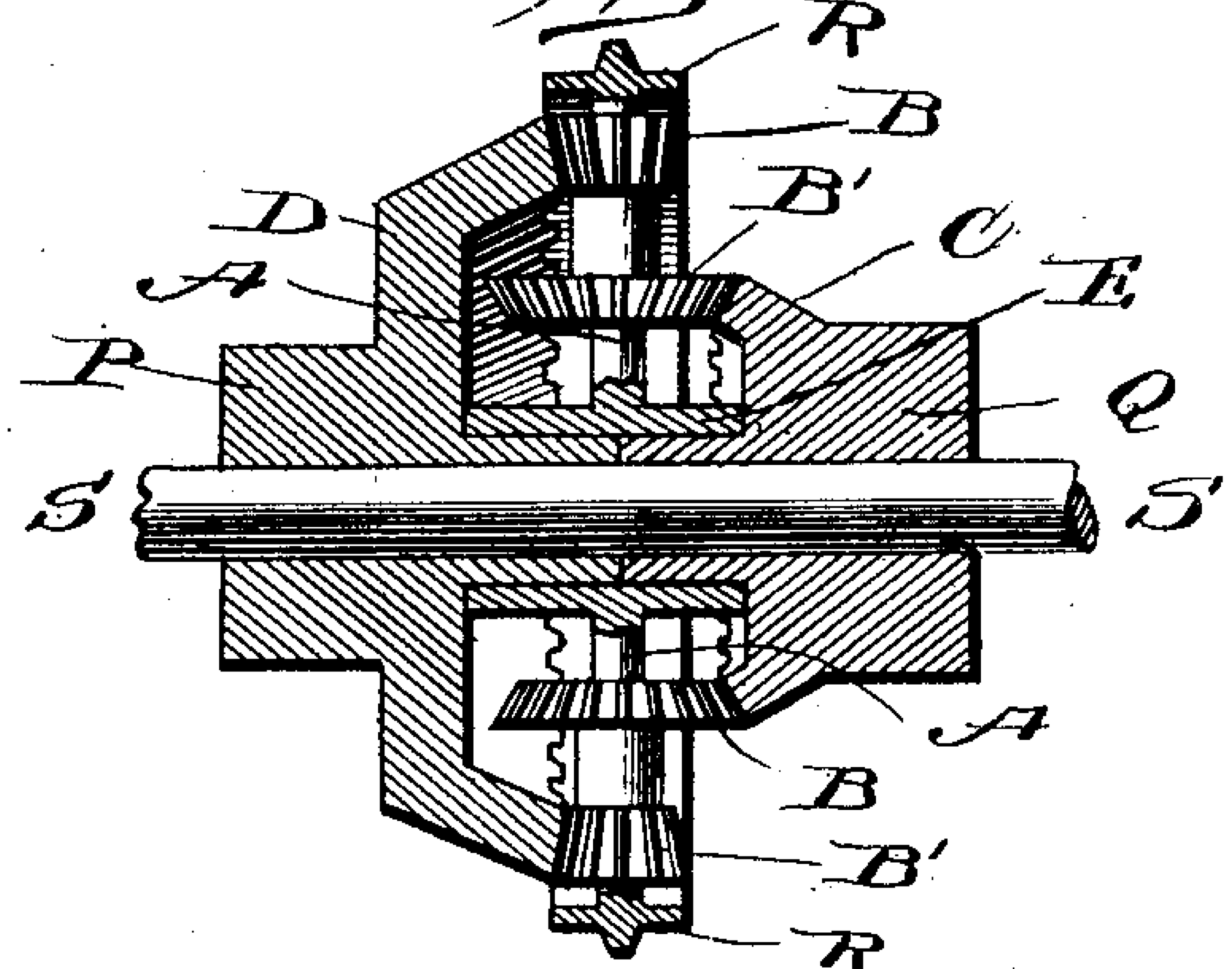


Fig. 2.

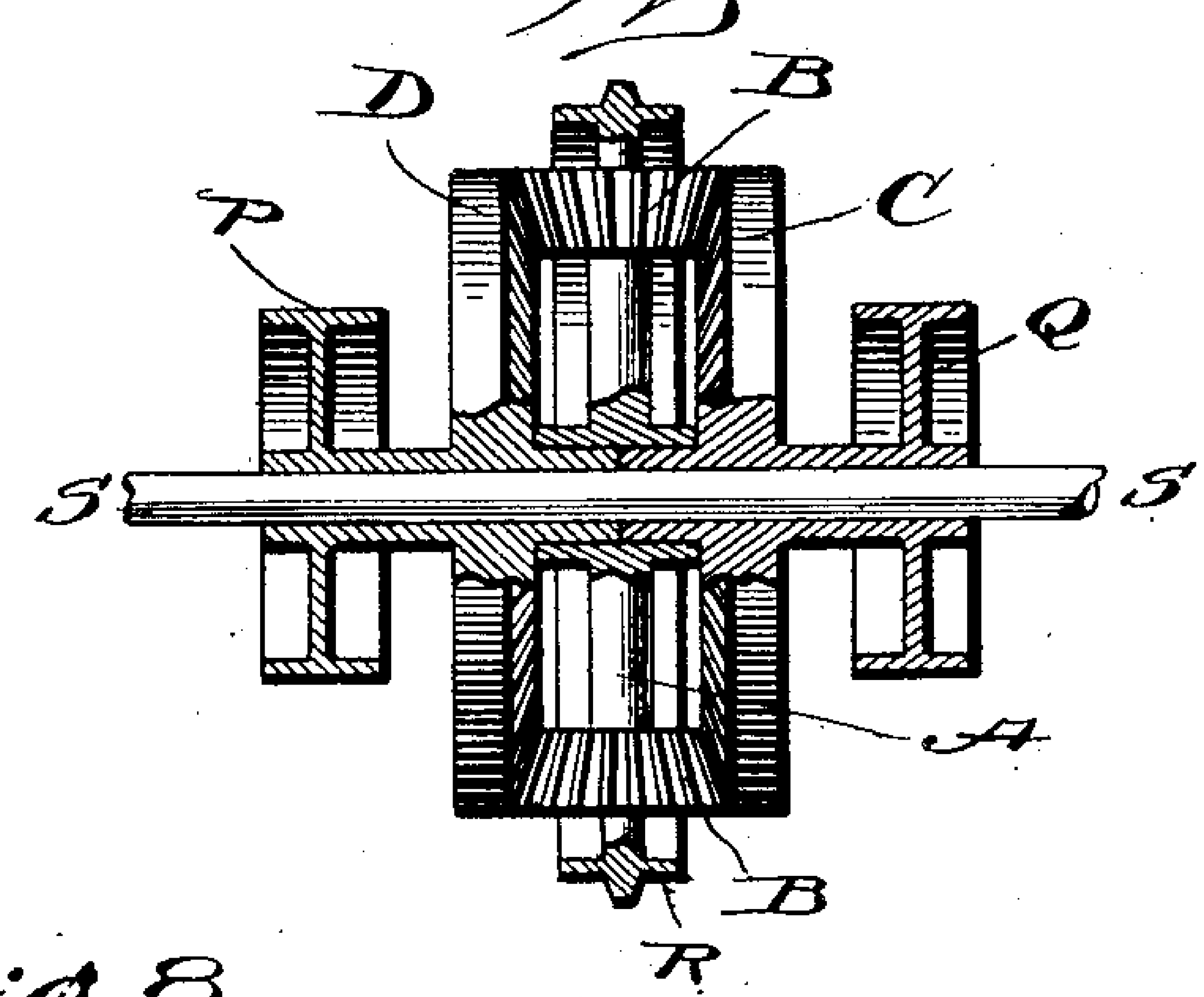


Fig. 8.

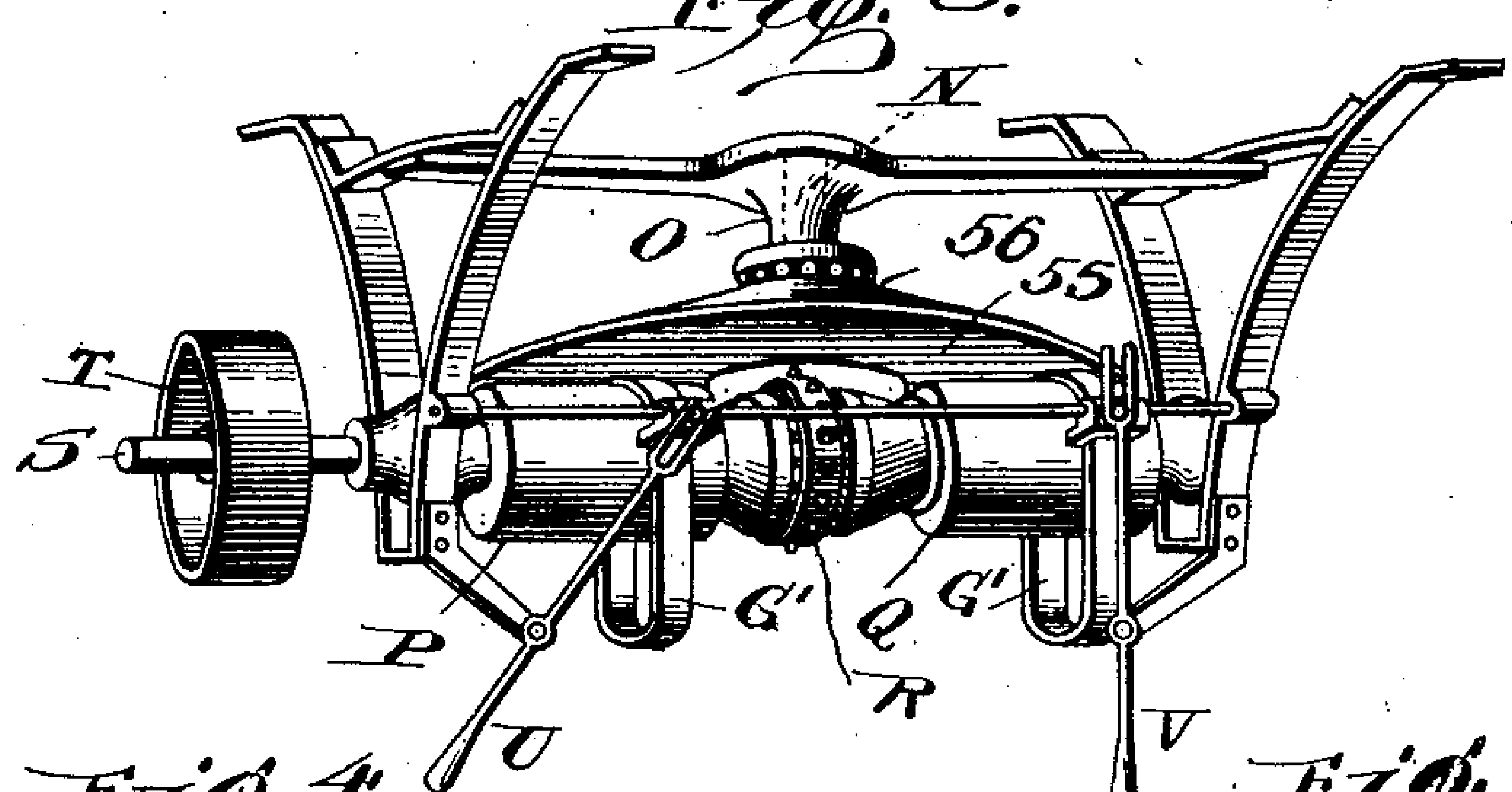


Fig. 4.

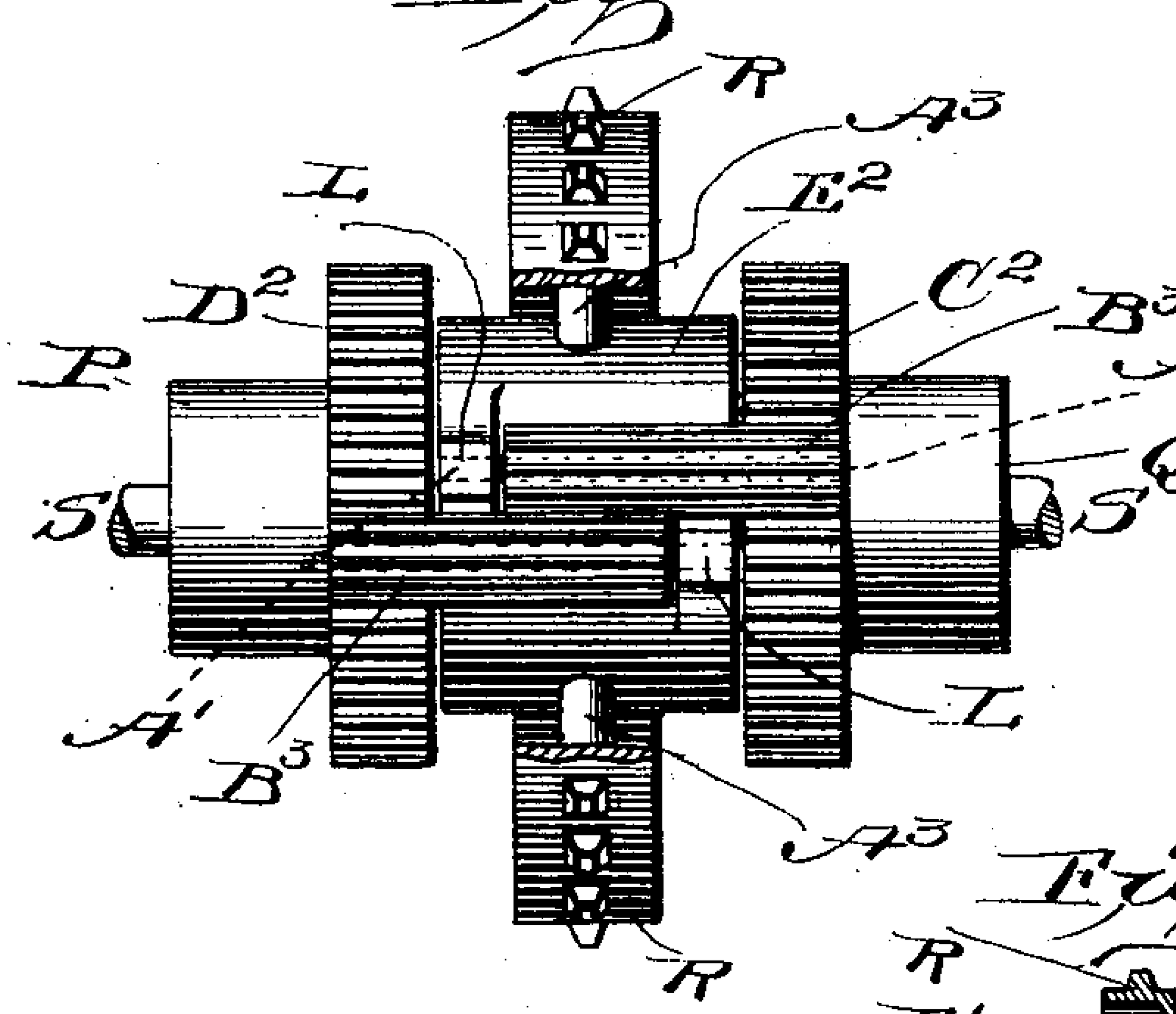


Fig. 5.

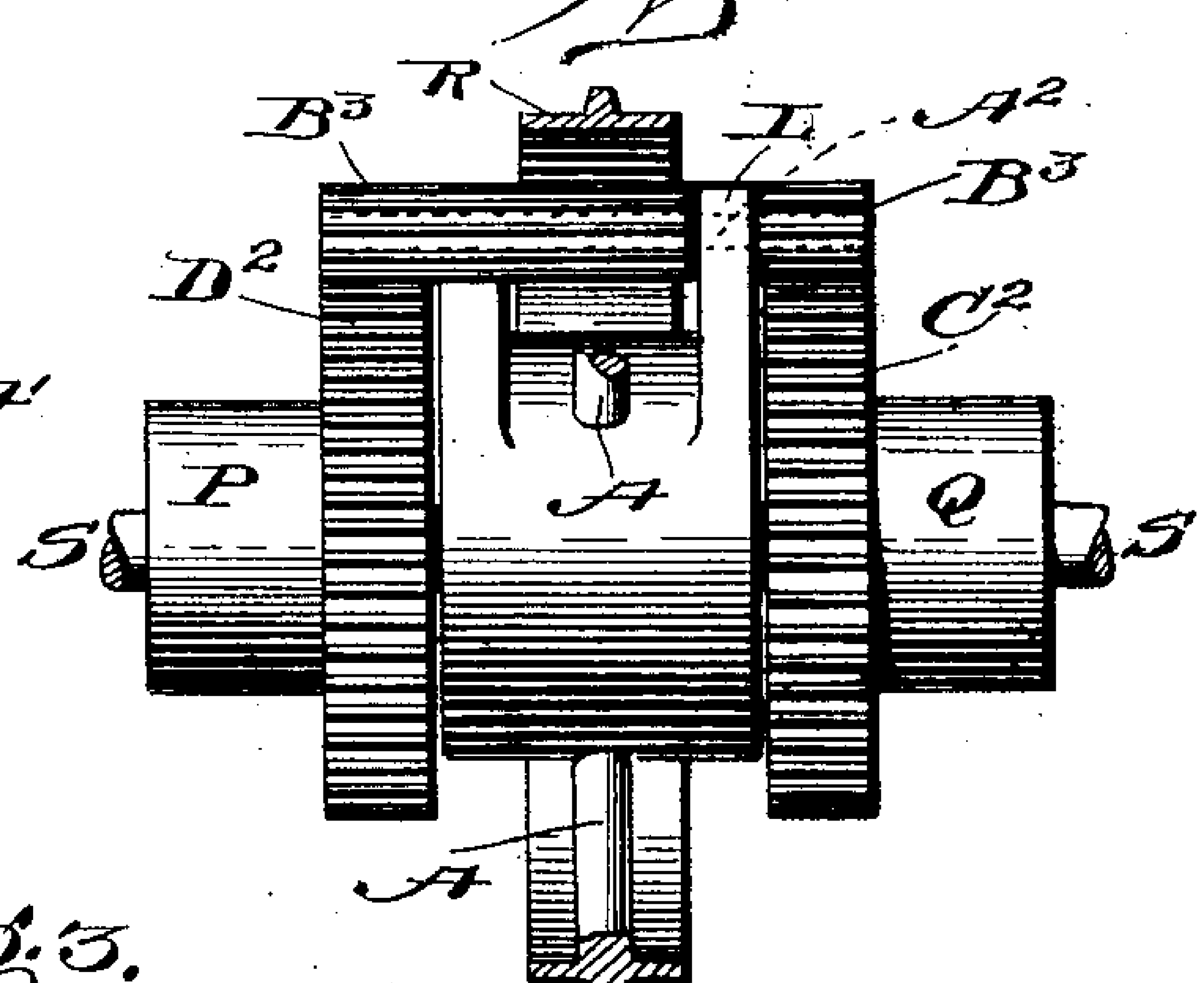
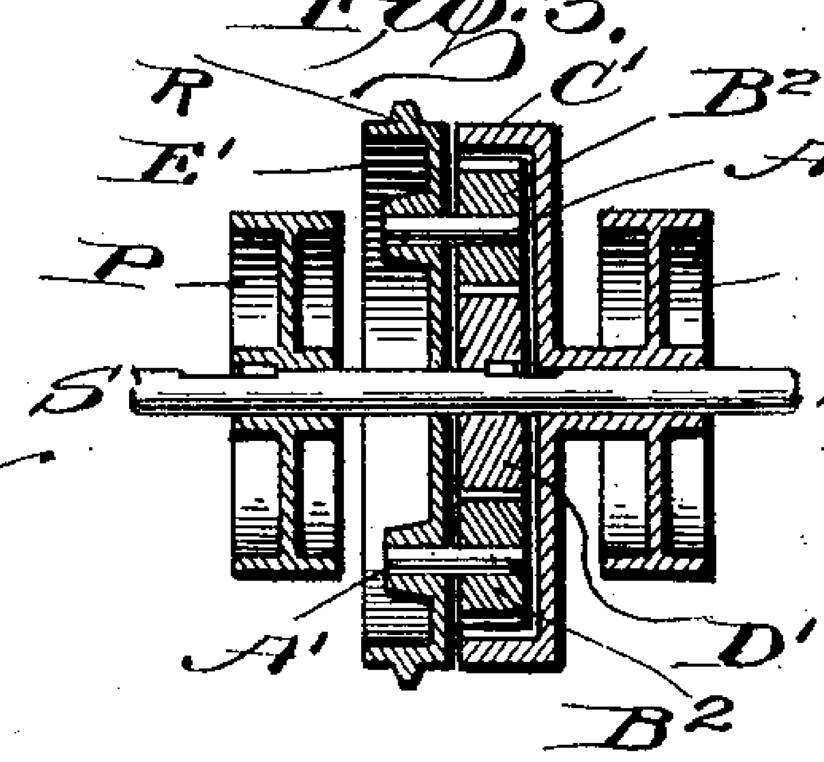


Fig. 3.



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APPARATUS FOR TRANSMITTING POWER.

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NO MODEL. 2 SHEETS—SHEET 2.

Fig. 9.

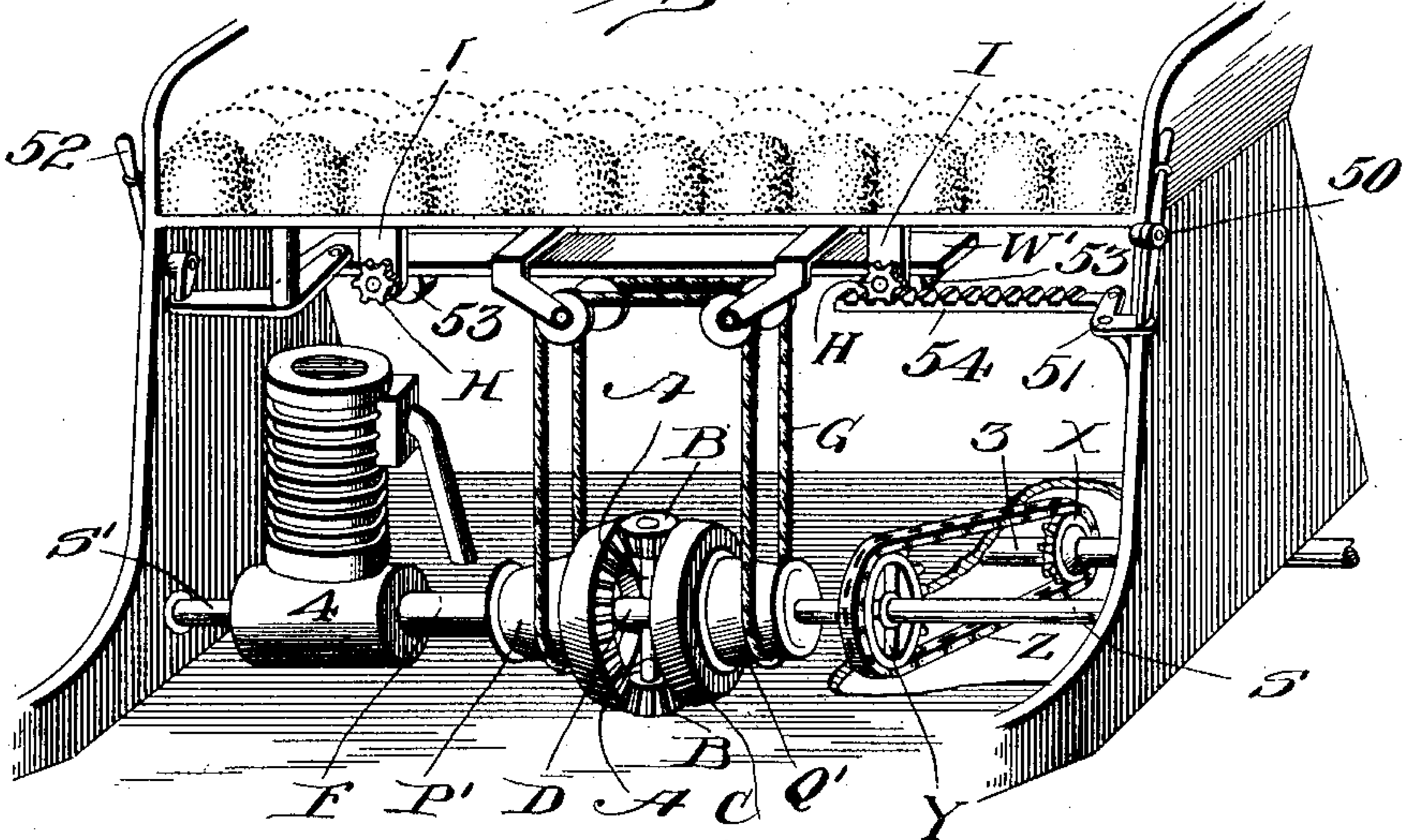


Fig. 10.

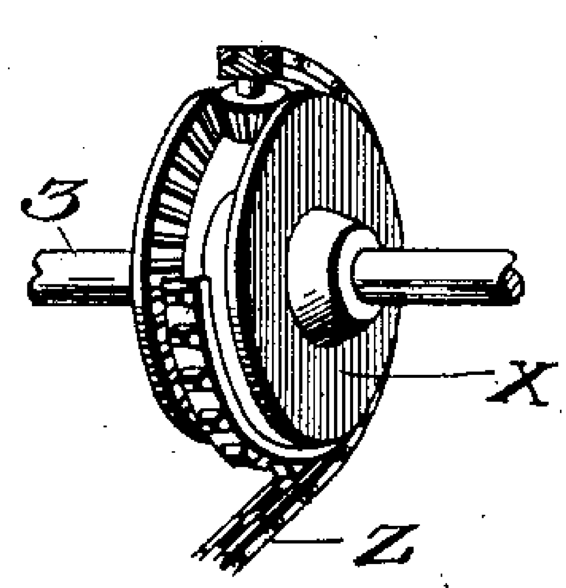


Fig. 7.

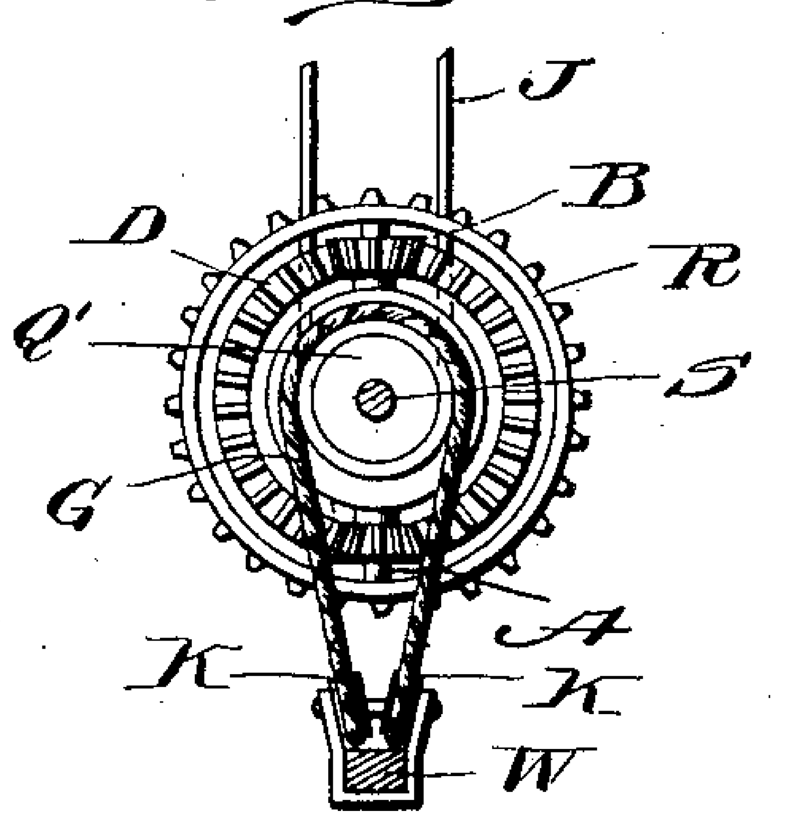
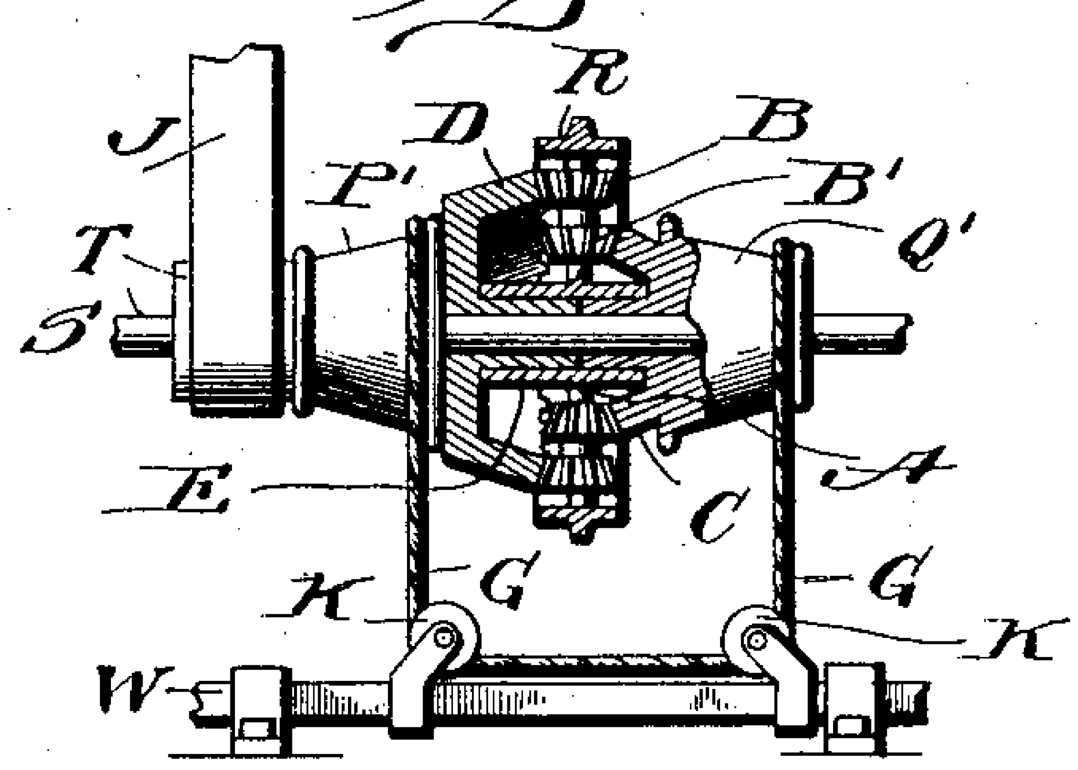


Fig. 6.



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No. 745,952. Patented December 1, 1903.

UNITED STATES PATENT OFFICE.

JOHN HALL BARNARD, OF NEWARK, NEW JERSEY, ASSIGNOR OF ONE-HALF TO BENJAMIN ATHA, H. G. ATHA, H. B. ATHA, AND C. G. ATHA, OF NEWARK, NEW JERSEY.

APPARATUS FOR TRANSMITTING POWER.

SPECIFICATION forming part of Letters Patent No. 745,952, dated December 1, 1903.

Application filed March 8, 1902. Serial No. 97,276. (No model.)

To all whom it may concern:

Be it known that I, JOHN HALL BARNARD, residing at Newark, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Apparatus for Transmitting Power, of which the following is a full, clear, and exact description, such as will enable others skilled in the art to which it appertains to make and use the same.

My invention relates to improved means for transmitting power, the process for which is disclosed in my prior application, Serial No. 79,624, filed October 23, 1901.

The object of the invention is to produce means whereby from a source of power not readily governable desired speeds may be obtained.

Further objects will appear from what is disclosed in the following description.

My invention consists in the novel arrangement and combination of parts, all of which will be understood from what is disclosed in the following description and illustrated in the accompanying drawings, which form a part of this application. In the specification of my prior application I have fully described and explained certain characteristics of that arrangement of gears known as the "planetary," "differential," or "epicyclic" train, which discovery renders them suited to a variety of uses to which their adaptability has not heretofore been recognized, so far as I know. The mechanisms for utilizing the principles are alike in that in all of them power is imparted to one member of such a train, producing in the other two members a resulting action and reaction which are equal and opposite, and so controlling by means substantially frictionless the work done by one equal part that the other equal part, transmitted to any desired purpose, is the exact amount required. They, however, resolve themselves into two general classes—first, one wherein the power developed in one of the other two members is returned to the driven member, and, second, the other wherein it is employed in operating a controllable load, which may have any or no relation to the purpose to which the other equal part is being devoted. In the first class the angular speeds of the driven and controlling members bear definite relations to each other for each position of the device through which the power is returned, thus producing definite speeds in the other member up to limits depending upon the power given to the driven member. In the second class, however, there are produced definite rotative efforts in the member directly connected to the machine to be operated, causing resultant speeds therein. The mechanisms for utilizing this second class form the subject of another application filed simultaneously herewith. This form of gears is capable of many arrangements, and I have herein shown four typical forms and given the algebraic expressions for the relative angular movements of the members of each for the purpose of clearly explaining the operation of my mechanisms and enabling others to adapt such gears to special purposes.

Referring now to the accompanying drawings for a full understanding of my invention when taken in connection with the following description, Figure 1 is an elevation, partly in section, of a train of gears having two bevel-gears of unequal diameter journaled loosely on the same shaft. Fig. 2 is a similar view of a train of gears having two bevel-gears of equal diameter also loosely journaled on one shaft. Fig. 3 is an equivalent train to that shown in the two prior figures, but of the spur-gear form. Fig. 4 shows still another arrangement of the spur-gears. Fig. 5 shows the same arrangement, but with the parts revolved through ninety degrees from the position shown in Fig. 4. Fig. 6 shows the form of that train of gears illustrated in Fig. 1, together with means for returning to the driven member the power developed by the reaction in one of the other two. Fig. 7 is an end view of the mechanism shown in Fig. 6. Fig. 8 shows that train of gears illustrated by Fig. 2 employed in connection with different means from that shown in Figs. 6 and 7 for returning the power resulting from the reaction in one member to the driven member. Fig. 9 also shows that train of gears illustrated by Fig. 2 on a power-vehicle for regulating the speed thereof in connection with the specific means shown in Figs. 6 and 7 for returning to the driven member the power of reaction developed in one of the other two members. Fig. 10 is a detail perspective view to more clearly show the compensating gear on the rear axle in Fig. 9.

In the different views of the drawings the same reference characters indicate the same part, and a letter or figure primed indicates a part performing a similar function, though of different form from the part indicated by the letter or figure itself.

In Fig. 1 of the drawings the parts lettered D and C are two bevel-gears of unequal diameter journaled loosely on the shaft S. A sleeve E is journaled loosely upon the hubs of D and C and carries the spindles A, which form the spokes of the rim R. Journaled loosely upon these spindles are the bevel-pinions B and B′, so attached to each other that they rotate as one. These pinions mesh into the gears D and C, respectively. The face of the rim R may be smoothed to carry a belt or provided with sprocket-teeth to engage a sprocket-chain or with gear-teeth to engage a gear-wheel. The bevel-gears D and C are also provided with pulleys or gear-wheels P and Q, respectively, attached to their faces, so that power may be conveyed to or from these members.

Fig. 2 shows a similar arrangement to that shown in Fig. 1, except that the gears D and C are of equal diameter, and in this case the pinions B and B′ are replaced by a single pinion B, engaging both the gears D and C.

In Fig. 3 is illustrated the arrangement of spur-gears wherein D′ is keyed to the shaft S. The spindles A′, carrying the pinions B^2, are studs projecting from the plate E′, which is loosely journaled on the shaft S. C′ is an internal gear also loosely journaled on the shaft S, and the pinions B^2 engage both D′ and C′. The plate E′ carries the rim R, and the gear C′, as in the other figures, is provided with a pulley Q, or it may be provided with its equivalent, a gear or sprocket wheel. The pulley P is represented as keyed upon the shaft S by which the gear D is rotated.

In Figs. 4 and 5, D^2 and C^2 are spur-gears, and E^2 is a cylinder journaled loosely upon the shaft S. The cylinder carries the lugs L, into which the spindles A′ A′ are set, carrying the pinions B^3 B^3, these pinions overlapping and engaging each other for part of their length, one engaging the gear D^2 and the other the gear C^2. The spokes A^3 carry the rim R, and D^2 and C^2 are provided with pulleys P and Q, respectively.

In the mechanism shown by these five figures let b represent the diameter of pinions B, B^2, or B^3; b', the diameter of B′; d, the diameter of the gears D, D′, or D^2, and c the diameter of the gears C, C′, or C^2, and let n and n'' represent the angular movement in a given time of D and R, respectively, about the common axis, and n' represent the corresponding angular movement of C in a direction opposite to that of D. Thus in the train of gears shown by Fig. 1

$$n = n'' + (n'' + n')\frac{b}{d} \times \frac{c}{b'}, \text{ (equation 1.)}$$

In the train shown by Fig. 2, $b = b'$ and $d = c$.

$$\text{Hence } \frac{b}{d} \times \frac{c}{b} = 1 \text{ and equation 1 becomes}$$

$$n = 2n'' + n', \text{ (equation 2.)}$$

In the train illustrated by Fig. 3, $b = b'$.

$$\text{Hence } \frac{b}{d} \times \frac{c}{b} = \frac{c}{b} \text{ and equation 1 becomes}$$

$$n = n'' + (n'' + n')\frac{c}{d}, \text{ (equation 3.)}$$

In the train illustrated by Figs. 4 and 5,

$$n = 2n'' + n', \text{ (equation 2.)}$$

If in any of these forms the rim R be driven, it is possible to produce in one of the others higher angular speeds than that in the driven member; but ordinarily it is more advantageous to drive one of the other members. Suppose, then, that D be driven, that the rim R be connected to the machine to be driven, and C used to govern the speed of R. Then, referring to the foregoing equations, it is clear that for every ratio of n to n', n'' assumes corresponding values. If in equation 1 $n = n'\frac{b\,c}{d\,b'}$ or in equation 2 $n = n'$ or in equation 3 $n = \frac{c}{d}n'$, n'' will equal 0 or the rim R will cease to revolve, even though D be driven as fast as possible. Likewise if in equation 1 $n'\frac{b\,c}{d\,b'}$ is greater than n or if in equation 2 n' be greater than n or if in equation 3 $n'\frac{c}{d}$ be greater than n, n'' will become a negative quantity, which means that R will rotate in the opposite direction to D.

Heretofore when a form of this system of gearing has been used to obtain variable speed ratios between the driven and the transmitting member the remaining member has been driven at variable speeds from some separate source or has been more or less restrained by a braking arrangement; but unless the controlling member be actually locked such braking entails a loss of fifty per cent. of the energy imparted to the train, for the pinions connecting D and C are virtually levers pivoted on the spindles A. Hence the moments about A are equal and the pressure on A equals the sum of the pressures transmitted by the teeth of D and C. If one of the members be locked, no work is done in that part, it becoming simply a fulcrum, and all the energy imparted to one of the other two members is transmitted to the other, the relative speed factors in each being obtainable from the above equations by making that of the locked member zero. If, however, none be locked, either by a device therefor or by a load too heavy to be moved by the pressure produced in that member, the second and third members will both revolve, as the result of their interaction and reaction, which can only be opposite and equal. Hence with sufficient torque available in the driven member the application of enough resistance to a second member will produce motion in the third resulting in equal work in each. Consequently the power absorbed by the driven member will have been divided into two parts equal to each other. Further, as it is a well-known physical law that with unit-power speed and resistance are the reciprocals of each other, consequently if we impose upon the controlling member a load that may be made to offer variable resistance we produce corresponding values of n', and so secure various values for n'' against its load. Satisfactory loads for this purpose are pumps and dynamos, for not only can the resistance they offer be easily regulated, but the energy expended in them is readily recovered for immediate use or for storage. Instead, however, of employing a secondary load for restraining the speed of the controlling member the energy developed in it may be returned to the driven member, and if the apparatus employed for returning it be capable of allowing various speed ratios between D and C varying values of n'' result.

In Figs. 6 and 7 I have shown one and in Fig. 8 another apparatus for securing definite ratios of speed between D in any of its forms and C in any of its forms.

In Figs. 6 and 7 the two bevel-gears D and C, which are loosely journaled on the shaft S, are made with the inner hubs of such length that they are kept apart the right distance to allow proper engagement with the two pinions B and B′. These rotate on the spindles A, that are carried by the sleeve E, which is loosely journaled on the hubs of D and C. An extension of D forms the cone-pulley P′ and the plain (or crowned) pulley T. An extension of C forms the cone-pulley Q′. The spindles A extended form the spokes of the rim R for connecting this member to the machine to be driven. About the cones P′ and Q′ is the belt G, guided from one to the other by the rollers K, carried by the rod W, so mounted that it may be moved in a direction parallel to the shaft S, thereby allowing the belt G to be shifted along the cones P′ and Q′. Power from any source is transmitted to the member D by the belt J, running on the pulley T. The rotation of D causes the pinions B and B′ and the gear C to rotate; but the relative motions of D and C being determined by the relative values of the diameters of P′ and Q′ where encircled by the belt G causes the rim R to rotate in the direction and at the speed measured by n'' in equation 1. If these cones be so proportioned that at an equal distance from corresponding ends the diameter of P′ bears such a relation to the diameter of Q′ that $n = n' \frac{b\,c}{d\,b'}$ and the belt be on the cones at said distance from the ends the rim R will not rotate. Any movement of the rod which shifts the belt to the right of this position causes R to rotate in one direction, and any movement that shifts it to the left causes R to rotate in the opposite direction. The farther the belt is shifted from this neutral point to the right or left the faster R rotates in the corresponding direction.

In Fig. 8 is shown another apparatus for governing the relative speeds of the driven and controlling members. In this apparatus, D and C are of equal diameters, as in Fig. 2. Instead of using cone-pulleys, as in Figs. 6 and 7, straight-face pulleys P and Q are substituted therefor. These carry the belts G′ G′, which operatively connect the pulleys and the plate 55 where desired. This plate rotates in its own plane about the spindle N in the bearing O. The thrust-bearing 56 minimizes the friction between the plate and the bearing O. The belts G′ are shifted to desired positions by the shippers U and V. As P and Q revolve in opposite directions and as the belts can best be managed at the side of entrance between the pulleys and plate, one of these shippers should be in rear of the pulley; but for clearness of illustration I have shown both in front, where they can be more distinctly depicted. From equation 2 it is seen that when P and Q revolve at equal speeds the rim R is at rest. If, therefore, the belts are so placed on their pulleys that they engage the plate 55 on the same circle, R stops rotating. If the shipper U is moved so as to carry its belt farther from the center of 55 than the other belt, R rotates in the same direction as D and at a speed dependent upon the relative paths the belts trace on 55. Vice versa, if by the shipper V its belt is placed farther from the center of M than the other belt, R will rotate in the direction of C at speed similarly varying.

It is apparent that expanding and contracting pulleys could be substituted for the cone-pulleys in Figs. 6 and 7, or friction-disks could be used instead of the straight-face pulleys P and Q and their belts G′ G′ in Fig. 8 such disks being arranged to slide on the shaft S to bear against the transmission-plate at variable distances from its center.

Fig. 9 is a perspective view of a motor-vehicle in which the first member D of the differential train is driven by the gas-engine 4, and the reaction developed in the member C is returned to the first member by the mechanism shown in Figs. 6 and 7. The shaft is in two pieces butted in the sleeve F, so that the two parts S′ and S revolve independently. The crank of 4 drives the member D through the sleeve F, to which D and the cone-pulley P′ are secured. As in the prior figures, P′, D, C, and Q′ are loose on the shaft S; but in this instance the spindles A A are attached to S, producing therein rotative effort, which is conveyed therefrom to the compensating gear X on the rear axle of the carriage by the sprocket-wheel Y and sprocket-chain Z. To allow the vehicle to coast under its own momentum, the shipper is arranged to be lowered, so as to slacken the belt. This is done by mounting the shipper on the hangers I and on the eccentric rollers 53, having a rack 54 and pinions H connected thereto. By throwing the lever 50, which is connected to the rack by a bell-crank 51, in one direction or the other the eccentric rollers will be rocked to raise or lower the shipper W′ and to either tighten or slacken the belt. The longitudinal movement of this shipper to shift the position of the belt G on the cone-pulleys P′ Q′ is accomplished through the bell-crank lever 52. The position of the belt G on these cone-pulleys P′ Q′ controls the speed of the vehicle, also the stopping of the vehicle, and also its reverse motion.

I am aware that others have made use of the differential gear in the solution of certain specific problems; but so far as I know the result in each case fails to disclose an appreciation of the full function of such gears, and their disclosures fail to make known the general characteristics of the internal reactions in a manner which exhibits its adaptability to the many broad uses that would logically follow. In some cases efforts have been made to minimize the loss through heat in the old friction-band by driving the third member by a worm actuated by the expenditure of a small amount of power taken from the face of the first member. In this case, however, it is impossible to conceive that the third member is reacting to return power to the first member through the worm. Furthermore, in this case the worm actually locks the third member if the friction-wheel used to drive the worm from the face of the first member be removed therefrom. In another case the electric reactions between two electric machines are employed, and it is essential that they alternately become dynamos and motors, thereby prohibiting that one of them be an induction-motor or a prime motor, such as a steam or an explosive-vapor engine.

It is obvious that changes may be made in the construction and arrangement of the parts as herein shown without departing from the scope or spirit of my invention. I therefore do not desire to be limited to the exact construction and form here shown.

Having now fully disclosed my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. In an apparatus of the class described, a train of gears, means for transmitting power to one member of the said train, means for connecting the second member to a load and means for returning to the first member the power developed by the reaction of the second member upon the third.

2. In an apparatus of the class described, a train of differential gears, means for transmitting power to one member of the train, means for connecting the second member to a load and a variable controlling device adapted to return to the first member the power developed by the reaction between the second and third members.

3. In an apparatus of the class described, a train of differential gears, means for transmitting power to the first member, means for connecting the second member to a load and a device adapted to determine the relative speeds of rotation between the first and third members and to return to the first member the reaction between the second and third.

4. In an apparatus of the class described, a train of differential gears, means for transmitting power to the first member of the train, means for connecting the second member to a load, a device adapted to afford a control of the relative speeds of rotation between the first and the third members and to return to the first member the reaction between the second and third members.

5. In an apparatus of the class described, a train of differential gears, means for continuously driving one member of the train, means for connecting a load with the second member and means for returning to the first member the energy resulting in the third.

6. In an apparatus of the class described, a train of differential gears, a pair of pulleys each of which is attached to one of two members of the train, a single continuous shaft centering the motion of all the members of the train and of the pulleys, means for driving one of the pulleys, means for varying and controlling the relative angular velocities of the two pulleys and means for transmitting to a desired load the power produced in the remaining member of said train.

7. In an apparatus of the class described, an axle, pulleys loosely journaled thereon, a differential gear between said pulleys, one member of the gear being connected to one pulley and another member to the other pulley, spindles of the remaining member connected to the axle, means for operatively connecting the pulleys and a shipper for changing the position of said means on the pulleys.

8. In an apparatus of the class described, an axle, pulleys loosely mounted thereon, a differential gear between said pulleys one member of the gear being connected to one pulley and another to the other pulley, the remaining member being connected to the axle and an endless belt passing over each of said pulleys, a device for shifting said belt on the pulleys, a sprocket-wheel connected to the axle, another axle, a compensating gear thereon, a sprocket-wheel connected to said gear and a sprocket-chain connecting the said sprocket-wheels.

9. In an apparatus of the class described, an axle, a motor, pulleys connected to said axle, a differential gear between said pulleys, one member of the differential gear being connected to one pulley, another to the other pulley, and the remaining member to the axle, an endless belt passing over each of the pulleys, a shipping-bar, sheaves carried by said bar for guiding the endless belt, means for moving the said bar and also means for lowering the bar in order that the belt may not be in operative contact with the pulleys, a sprocket-wheel on the axle, another axle, a compensating gear on the second axle a sprocket-wheel connected to said gear, and a sprocket-chain connecting the two sprocket-wheels, as and for the purposes set forth.

In testimony whereof I affix my signature in the presence of two witnesses.

JOHN HALL BARNARD.

Witnesses:
H. M. SEAMANS,
I. C. DELANEY.