

April 18, 1933.

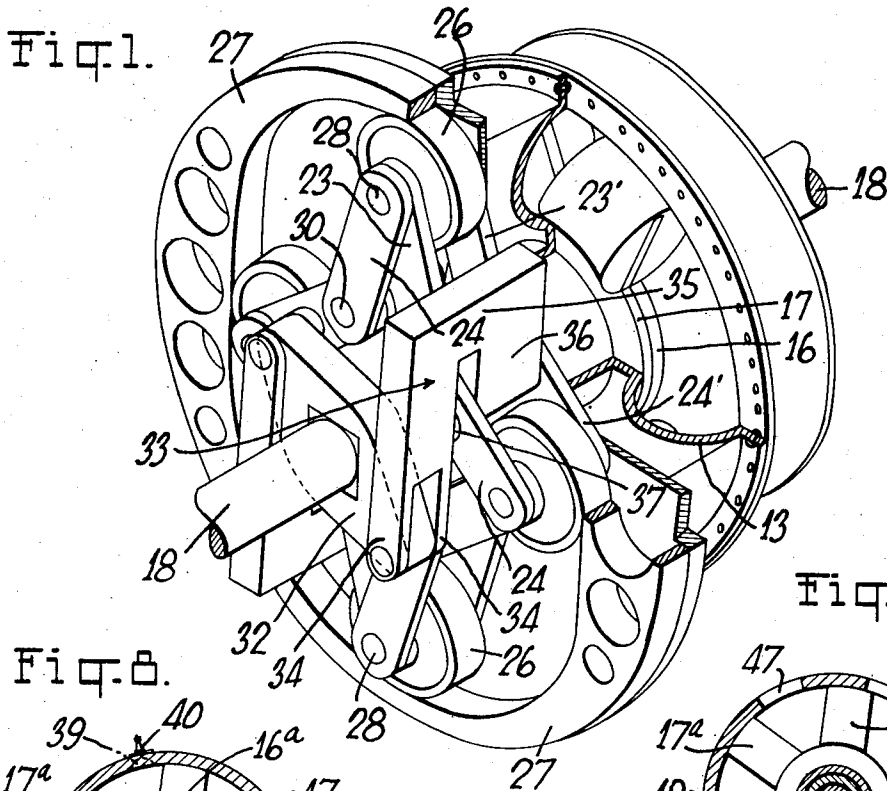
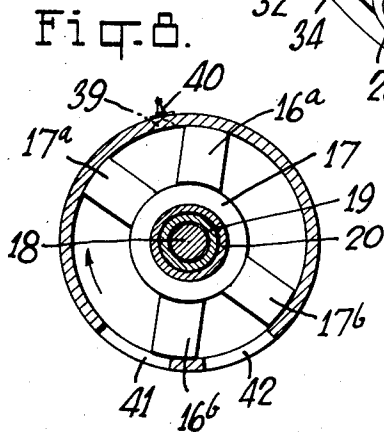
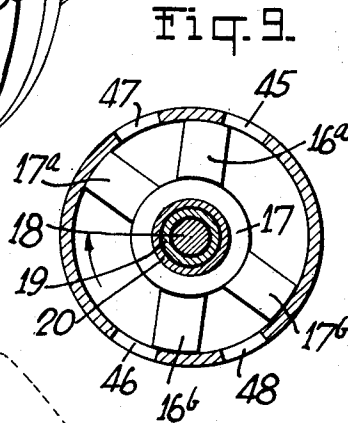
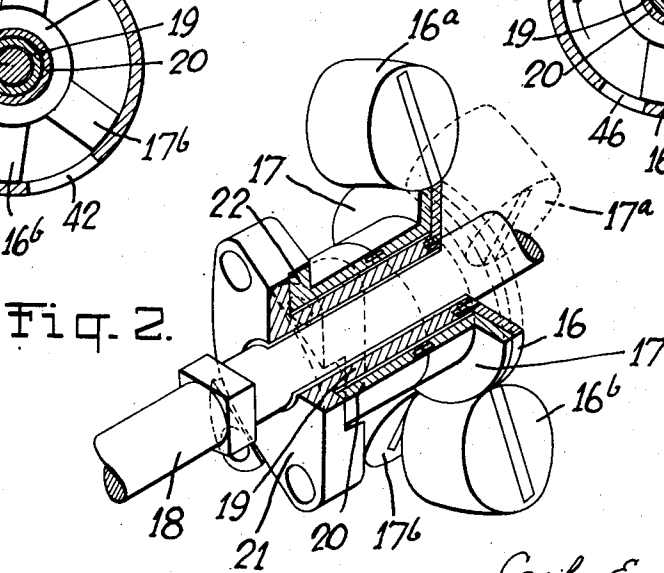
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1,904,892

ROTARY ENGINE COMPRESSOR AND THE LIKE

Filed Jan. 28, 1930

4 Sheets-Sheet 1



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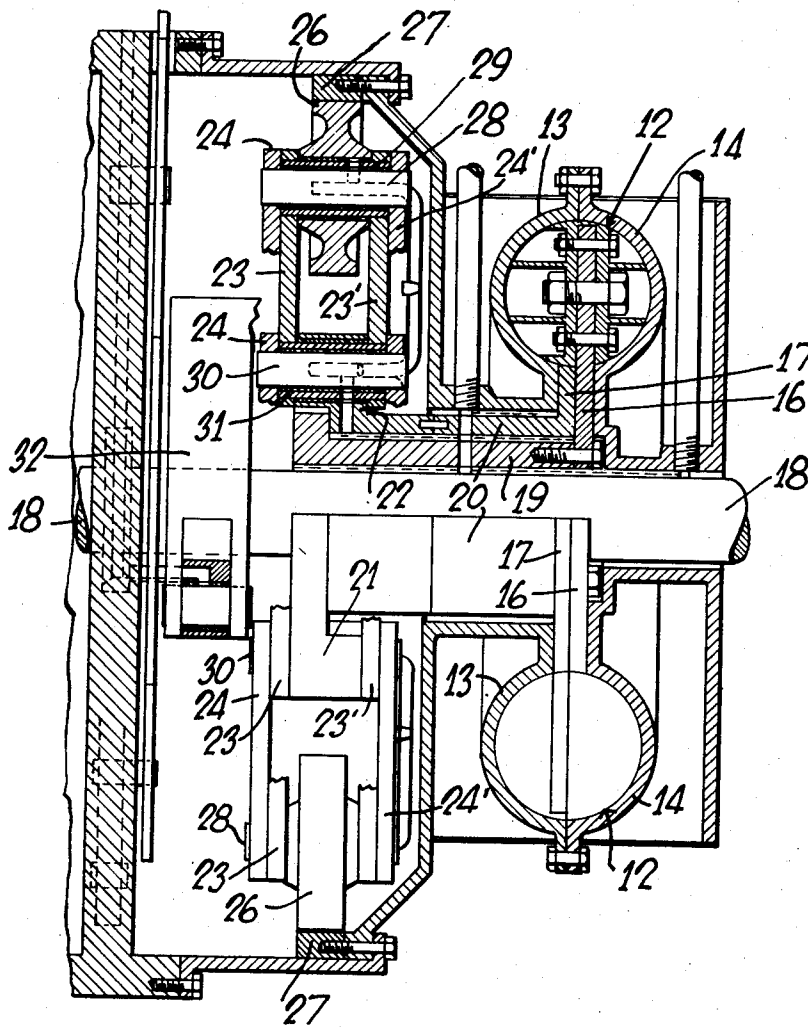
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Fig. 3.



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Fig. 4.

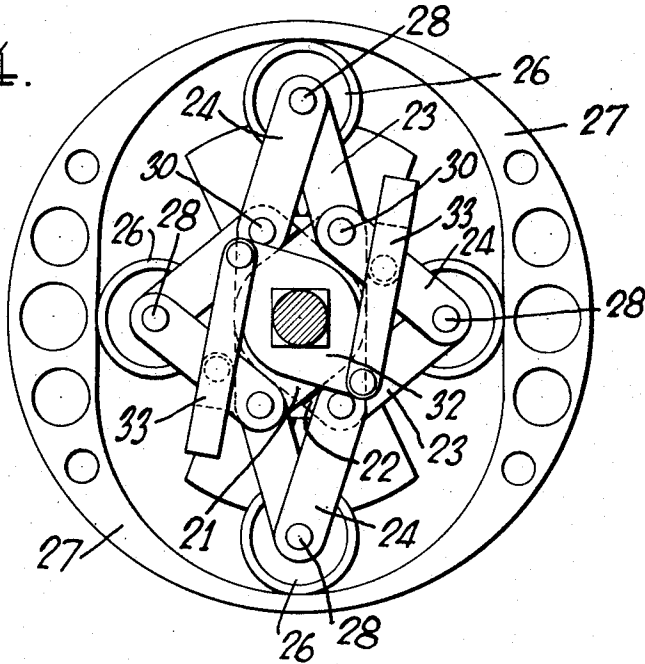
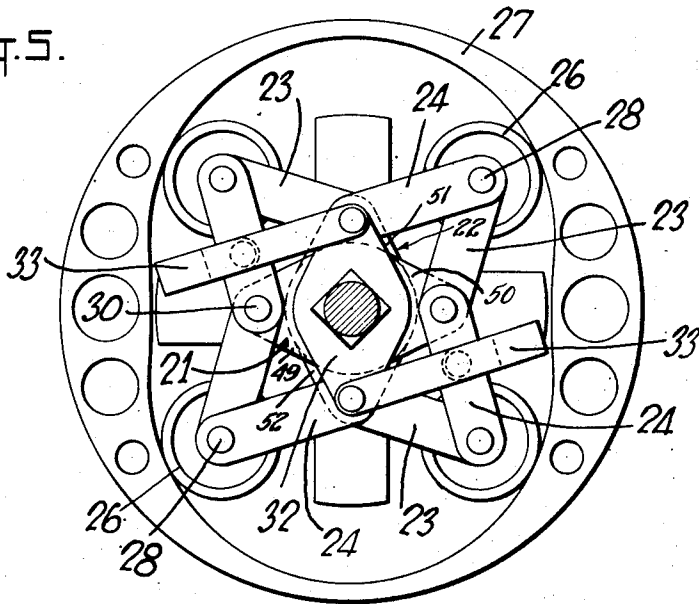


Fig. 5.



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4 Sheets-Sheet 4

Fig. 6.

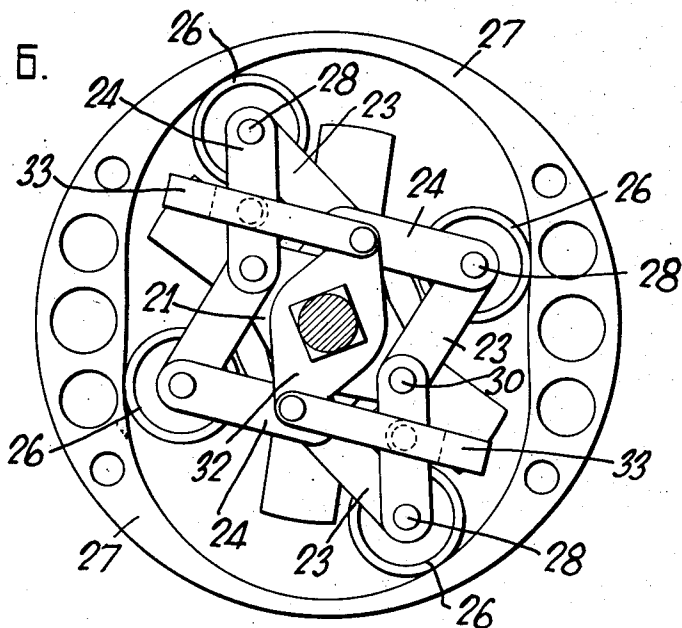
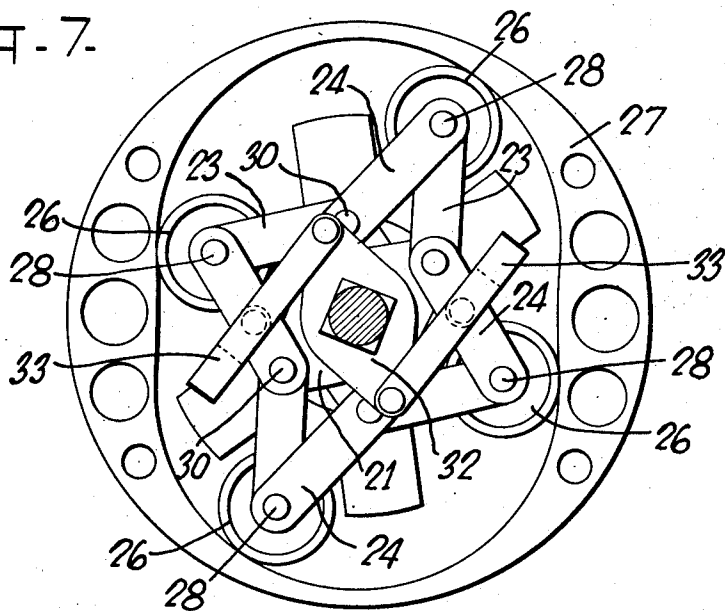


Fig. 7.



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UNITED STATES PATENT OFFICE

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ROTARY ENGINE COMPRESSOR AND THE LIKE

Application filed January 28, 1930. Serial No. 423,922.

This invention relates to machines and mechanisms, such as rotary internal combustion engines, rotary steam engines, rotary compressors, and the like, wherein a plurality of pistons rotating in a continuous annular cylinder are employed in converting gas-pressures into piston movement, or vice versa, and particularly to machines of this general character wherein the pistons are adapted to have a relative movement toward and away from each other while rotating about the central axis of an annular cylinder; and to correlated inventions and discoveries appertaining thereto.

In general, it is an object of the invention to provide a machine of the character set forth, which is simple, sturdy and permanent in construction, which may be readily and economically manufactured and assembled, and which will efficiently accomplish the purposes for which it is intended.

Among the other objects of the invention are the provision of improved means for transmitting power between a rotatable shaft and pistons capable of a combined angular and reciprocatory movement; the provision of a machine having improved operating characteristics; and the provision of a machine which occupies a relatively small space and which is relatively light in weight.

Another object is the provision of a machine wherein the relative movement of the parts is such as to secure a particularly efficient utilization of power.

Another object is the provision of a machine wherein the parts are so constructed and arranged that the stresses due to operation will be distributed so as to assure the long life of the machine.

Another object is the provision of a simple and compact machine wherein the wearing effects due to lateral twisting forces are minimized.

Another object is to provide improved means for connecting a rotatable member with members movable angularly about the axis thereof.

Other objects of the invention will in part be obvious and will in part appear herein after.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts, which will be exemplified in the constructions hereinafter set forth and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Figure 1 is a perspective view of a machine embodying the invention with portions broken away to reveal the working parts;

Fig. 2 is a detail perspective view showing the sleeves and associated members with portions thereof cut away, and showing also a portion of the shaft;

Fig. 3 is a vertical section with certain of the parts shown in elevation;

Fig. 4 is a somewhat diagrammatic face view of certain parts of the mechanism;

Figs. 5, 6 and 7 are similar views showing the parts in various positions;

Fig. 8 is a diagrammatic view of portions of a machine such as exemplified arranged to operate as an internal combustion engine; and

Fig. 9 is a diagrammatic view of portions of a machine such as exemplified arranged to operate as an engine operated by externally evolved fluid pressure, or as a compressor.

In a machine of the character under consideration, it is desirable to connect the pistons with a suitable driven element—in the case of an engine—or to a suitable driving element—in the case of a compressor—, by means of mechanism which assures an efficient transmission of power, which has a long life, which is compactly arranged, in which vibration due to the varying movement of the parts is minimized to an extent required by practical considerations, and which is compactly arranged and of relatively light weight. Various mechanisms involving cam controlled rollers and link-work have been proposed for use in such a machine, it being the general practice to pivotally mount the rollers at the corners of an equilateral link-work which is deformed

from square to rhomb shape and vice versa in the course of movement of the rollers, each link being pivotally connected at its center to one or another of crank arms having a movement corresponding to that of the pistons, the radius of each crank arm being equal to half the length of each link. Such mechanisms, so far as is known, are inherently incapable of arrangement in such manner that the same will operate efficiently from the practical standpoint and at the same time have sufficient strength and resistance to wear permanently and efficiently to carry the loads imposed upon them. The present invention contemplates the provision of a machine whereby these and other disadvantages are overcome, and which embodies, among other features, a practical and workable connecting mechanism of a character such that power is applied in a particularly efficient and even manner.

In the exemplified embodiment of the invention there is provided an annular cylinder 12, the greater portion of the walls of which are formed of oppositely disposed members 13 and 14 arranged to provide an annular opening along the inner surface of the cylinder. Within the cylinder there are a plurality of pistons arranged in sets, each set being integral with, or suitably connected to, one of a plurality of rotatable discs, the major portion of the peripheral surfaces of which provide part of the cylinder walls. In order to minimize the number of these discs, it is desirable to provide a minimum number of piston sets, and it is ordinarily desirable to have the pistons arranged in diametrically opposed pairs, particularly when the machine is to be used as an internal combustion engine. In the present instance, there are provided diametrically opposed pistons 16a and 16b on a disc 16 and diametrically opposed pistons 17a and 17b on a disc 17.

In the exemplified construction the element which is driven by the pistons or which drives the pistons, as the case may be, consists of a central rotatable shaft 18. A sleeve 19, movable with the disc 16, is rotatably mounted on the shaft 18; and a sleeve 20, movable with the disc 17, is rotatably mounted on the sleeve 19. In order to connect the sleeves 19 and 20 with the shaft 18 there is provided suitable means comprising link-work carrying control elements guided by a cam surface, whereby the rotating and reciprocating movements of the sleeves may be combined in a rotating movement of the shaft.

As will be seen particularly from Fig. 2 the sleeve 20 carries at its outer end a crank 22, and the sleeve 19 projects slightly beyond the end of the sleeve 20 and carries on its projecting portion a crank 21. The central portion of each crank is recessed to receive the other. The cranks 21 and 22 are arranged, in

the present instance, with diametrically opposed arms 49 and 50 and 51 and 52, respectively, movable in a single plane. Pivotally secured to the ends of the crank arms are suitable pairs of diverging links or link members; there being provided, in the present instance, a link 23 and a link 24 on each arm. The outer end of each link 24 on one crank is pivotally connected to the outer end of a link 23 on the other crank; and a suitable control element such as a roller 26 is rotatably mounted, in the present instance, at such pivotal connection. The rollers 26 are arranged to move within a cam member 27 providing an internal cam surface designed to permit such roller movement as will properly control the relative link movement in the link-work.

The links 23 and 24 connected to each crank arm may be integral with each other, but, preferably, and as exemplified, are made independent so as to permit relative angular movement between the two. By such a construction relative movement between adjacent rollers is permitted, so as to prevent excessive strain on the parts as the normal relative positions thereof are altered slightly from wear, as in the bearings and on the cam surface. This feature, moreover, permits the construction of a machine wherein power is transmitted between the pistons and the shaft through the medium of mechanism arranged to operate most effectively when adjacent control elements move with respect to each other.

In a machine of the character under consideration it is of extreme importance to minimize lateral twisting forces and to avoid, as far as possible, any unbalanced thrusts. Not only does this render possible the provision of a compact, relatively light-weight machine having sufficient strength to withstand its operation requirements, but also greatly extends the life of the machine. With these ends in view, the present machine comprises duplicate links 23' disposed on the opposite side of the crank arms and rollers from the links 23 and duplicate links 24' disposed on the opposite side of the crank arms and rollers from the links 24. Thus, in the present instance, links are provided in the duplicate on each side of a plane perpendicular to the cam surface and intersecting this surface, so that lateral twisting forces between the crank arms and the rollers are substantially eliminated, the thrusts exerted by these members being evenly balanced. By the elimination of lateral twisting forces stresses on the parts of the mechanism are minimized and the wear on the bearings is reduced to a minimum. In the present instance, the balancing of the forces and the reduction of wear is even more effectively obtained by securing the outer ends of each set of links 24—24' to the ends of a pin 28 carrying a centrally

mounted rotatable sleeve 29 to the ends of which the outer ends of a set of links 23—23' are secured. The inner ends of each set of links 24—24' are secured to the ends of a pin 30 carrying a centrally mounted rotatable sleeve 31 to the ends of which the outer ends of the set of links 23—23' are secured. The rollers are rotatably mounted on the sleeves 29 and the crank arms are pivotally mounted on the sleeves 31 so that each of these members is movably mounted on a sleeve and is held against lateral movement by the links 23—23' which are secured to the sleeves. Lateral movement of the sleeves is prevented by the links 24—24' which are secured to the solid pins. As will be seen, all forces transmitted by the links 24 and 24' and 23 and 23' will be taken up and distributed over the laterally extending bearing surface between the pins and the sleeves. Wear on the surfaces of the links themselves is avoided. The link-work is kept from being twisted out of alignment, due to the fact that all link and roller forces are balanced. It will be obvious that in a machine of the type under consideration the avoidance of excessive wear, as well as the avoidance of unusual strains, is of particular importance in order that a machine which works efficiently and has a sufficiently long life for practical purposes may be provided.

In order that power may be transmitted to or from the shaft, as the case may be, the mechanism already described is interconnected, preferably by means including one or more pivotally mounted links. I have found that it is of importance to join the roller link-work with a shaft-link at a point internally of the outer pivotal connection of the roller links such as the links 23 and 24, and preferably at a point well within an angle having its vertex on the axis of the shaft and its sides intersecting the pivot points on the link to which it is connected, the best results being ordinarily obtained by having this point of connection in the inner part of the central half of such an angle, i. e., in that portion of the middle section of a link, such as 23 or 24, which is adjacent the crank to which such link is connected.

In the present instance there is pivotally connected to each end of a crank 32, which is fixedly mounted on the shaft 18, a hook-shaped shaft-link 33, the exemplified link being formed with a pair of spaced arms 34 which extend on opposite sides of the crank and tend to prevent lateral twisting forces at the point of connection. Each link 33 extends outwardly adjacent a link 24 and laterally beyond the same as at 35 and is formed with a portion 36 which extends inwardly between the link 24 and a corresponding link 24', and is pivotally connected with these links by means of a pivot pin 37 which is mounted on the links 24 and 24' at a point between pins 28 and 30 and somewhat nearer the

latter than the former pin. This point of connection not only permits a link arrangement wherein lateral twisting forces are minimized and whereby the construction of a compact machine, the parts of which have the desired strength and size, is assured; but also results in a reduction of the moment of inertia in the shaft-link itself and in the stress in this link as compared with a construction wherein this link is connected at the outer end of a link member. This feature of construction also permits a greater freedom in the relative arrangement of the associated elements and permits the construction of a smoother running machine, one wherein the application of force is more effectively controlled, it being observed that in a construction wherein the kinematic application of force to or by the shaft is made dependent upon the positions of a crank and a roller, for example, a wide range of possibilities in the design of a smooth running and compact machine is opened up.

As will be seen more particularly from Fig. 4, each of the links 23 and 24 and 23' and 24' has a length from pivot point to pivot point which is greater than the radius of the arms of the cranks 21 and 22. There thus results, in the present instance, a star-shaped configuration of the links which provides a recess or concavity between adjacent rollers so as to provide ample room for the movement of the laterally extending portion 35 of the hook-shaped shaft-links 33. The provision of such a recess permits the lateral portion of each of these links to be made sufficiently strong to withstand the maximum stresses which may be imposed upon it and at the same time to clear the cam surface which guides the rollers. An arrangement such as exemplified permits a reduction in the wear of the parts and in bringing all of the parts closer to the axis of the shaft and also permits a construction embodying rollers having a relatively large radius and the ready design of the cam having the desired characteristics for efficient operation; and permits the construction of a machine having a smaller overall diameter than would be the case in a machine of equal capacity having a parallel sided link-work. The provision of a machine having relatively long roller links, moreover, permits the design of a cam having a smoother curve than would otherwise be the case; so that the stress and wear in the parts is minimized and the construction of a smooth running machine having a long life is facilitated. It will be apparent, moreover, that the use of a mechanism including my improved type of link-work gives rise to no mechanical or dynamic disadvantage.

It will be apparent that the mounting of a connecting link intermediate the pivot points on the crank arms, which turn with the pistons, and on the adjacent control elements, as

well as the provision of a recess for the reception of a laterally extending portion of this link, and certain other features of the invention, are features independent of the provision of separate link members, such as 23 and 24, and are of advantage in machines wherein centrally pivoted links composed of integral link members are pivotally connected at their outer ends with the link members of other centrally pivoted links.

The actual point of connection of a shaft link with a roller link will be determined by the size and formation of the various parts such as the control elements, links and cam, and by the requirements of the mechanism for the even transmission of power, it being ordinarily preferable to mount this link in the inner or central half of the angle above described and preferably toward the side of the angle adjacent the pivot connecting the link and a crank arm.

In Fig. 8 there is illustrated diagrammatically a cylinder arrangement in a machine such as described above which is adapted to be utilized as an internal combustion engine. A portion of the cylinder is provided with a recess 39 in which is disposed a spark plug 40, and openings providing an intake port 41 and an exhaust port 42 are provided in an opposite portion of the wall, preferably on either side of a diameter of the cylinder which is disposed beyond the spark plug in the direction of movement of the pistons. The actual location of ports in any given machine may be determined by the timing desired.

Fig. 9 illustrates diagrammatically a cylinder arrangement in a machine such as described which is adapted to be utilized as a compressor, steam engine or an analogous device. In this arrangement intake ports 45 and 46 are provided at diametrically opposed points and diametrically opposed exhaust ports 47 and 48 are at points adjacent the aforesaid ports.

The manner of operation of a machine such as exemplified, will be readily apparent from the foregoing. Movement of the adjacent ones of the pistons away from each other, as, for example, upon the explosion of a charge in an internal combustion engine, will be accompanied by a rotation of the pistons at varying speeds and a movement of the control elements and link-work from the position shown in Fig. 4, through the position shown in Fig. 7, to the position shown in Fig. 5, thence to the position shown in Fig. 6, and thence to a position which is symmetrical with the position shown in Fig. 4. In the meantime each of the pins 37 connecting the hook-shaped links 33 with the links 24 has traversed a path such that the ends of the shaft-crank 32 are moved at a constant speed about the axis of the shaft, due to the varying angularity of the hook-shaped links. Thus,

the rotation of the shaft will be constant, while movement of cranks such as the cranks 21 and 22 will be a combined rotation and relative reciprocation.

There is thus provided a mechanism which is equally adapted for use in the transmission of power in various types of rotary engines and in rotary compressors and which can be incorporated in a simple and compact machine. A mechanism embodying the invention as especially adapted for the efficient transmission of power can be readily utilized in various forms and is adapted to be so constructed as to resist wear and stresses, such as would materially shorten the life and easily break down an ordinary machine.

While the member which is driven by power derived from the pistons, or which supplies the power to drive the pistons as the case may be, is, for the sake of facility of expression, referred to as a "shaft" in the appended claims, it is to be understood that the term "shaft" as used therein is not too limited to any particular type of rotatable driven or driving member, but is to be understood as embracing any type of rotatable member which may serve the purposes of a shaft.

Since certain changes may be made in the above construction and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which as a matter of language might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, means providing an internal cam surface, a plurality of control elements movable along said cam surface, means including link-work for connecting said control elements with each set of pistons, and means including a link pivoted to the aforesaid link-work at a point spaced a substantial distance internally of said control elements for connecting said link-work with said shaft.

2. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, means including pivoted link-work connecting said piston sets one with another, means to

control the movement of said link-work, and means pivoted to an intermediate link of said link-work at a point spaced a substantial distance from each of a pair of its pivot points to connect said link-work with said shaft.

3. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a plurality of control elements, means including link-work for connecting said control elements with each of said sets of pistons, and means including a Z-shaped link-work for connecting one of said control elements with said rotatable shaft.

4. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons movable within said cylinder, means uniting the pistons in each set, means providing an internal cam surface, a plurality of control elements movable along said cam surface, link-work pivoted to each of said uniting means and arranged to connect each uniting means to said control elements, and means including a link pivoted to the aforesaid link-work at a point within an angle having its vertex on the axis of said shaft and having its sides intersecting a pivot point where said link-work joins one of said uniting means and a pivot point on said link-work adjacent one of said control elements for connecting said link-work to said shaft.

5. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer ends of said link members, a controlling cam, a crank on said shaft, and a link pivoted to said latter crank and pivoted to one of the aforesaid link members at a point within an angle having its vertex on the axis of said shaft and its sides intersecting the pivot points of one of said link members.

6. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer ends of said link members, a controlling cam, a crank on said shaft, and a link pivoted to said latter crank and pivoted to one of the aforesaid link members at a point within the central half of the angle having its vertex on the axis of said shaft and its sides intersecting

the pivot points of said one of said link members.

7. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer ends of said link members, a controlling cam, the distance between the pivot points on each of said link members being greater than half the distance between the adjacent points of connection of pairs of link members.

8. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer ends of said link members, a controlling cam, the distance between the pivot points on each of said link members being greater than half the distance between the adjacent points of connection of pairs of link members, and means including a link pivotally connected to one of said link members intermediate its pivot points, for connecting the aforesaid link-work to said shaft.

9. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of pistons movable within said cylinder and arranged in diametrically-opposed pairs, a crank movable with each pair of pistons and having arms corresponding to each piston, a link pivotally connected to each crank arm, adjacent pairs of links being pivotally connected one with another, a control element carried at the interconnected ends of said links, and a cam surface providing a guide for said control elements, a crank on said shaft, and means providing a pivoted link connection between said shaft crank and one of the aforesaid links, the point of connection with said link being included in an angle having its vertex at the center of the shaft and its sides between the pivot points on one of said links.

10. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons, means providing a controlling cam surface, control elements movable along said surface, a crank having a movement corresponding to the movement of each piston set, pivoted link connections between the ends of said crank and said control elements, bearings carried by certain of said links and movable in a path internally of the pivot point at which said control elements are connected, and

means including a link pivotally mounted on said bearings for transmitting movement between the aforesaid links and said shaft.

11. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, means connecting said sets of pistons with said shaft, said means including pivoted link-work, control elements carried externally thereby, and a controlling cam, said link-work and said cam being arranged to move said control elements in a path outside of the path of movement of the inner pivot point of said link-work.

12. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer ends of said link members, a controlling cam, said link members and said cam being adapted to maintain said control elements at a greater distance from the center of said shaft than the radius of said cranks, and means including a link to connect one of said link members to said shaft.

13. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, means including link-work for connecting said sets of pistons with said shaft, a plurality of control elements, and a cam surface arranged to limit the movement of said control elements, each of said control elements being mounted on said connecting means, and said connecting means being arranged to permit a relative angular movement between said control elements and said shaft.

14. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, means providing an internal cam surface, a plurality of control elements movable along said cam surface, a pair of angularly movable pivotally connected link members disposed on one side of each of said control elements, a similar pair of link members disposed at the other side of each control element, one link member of each pair being connected to one set of pistons and another link member of each pair being connected to another set of pistons, and means connecting the aforesaid link-work with said shaft.

15. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer end of the point of connection of said link members, a controlling cam, each of said link members being arranged in duplicate, one on each side of a plane intersecting said control elements, a crank on said shaft, and means to transmit power between said shaft-crank and certain duplicate ones of said link members, said means being connected to said link members at a point between the duplicate link members and between the ends thereof.

16. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer end of the point of connection of said link members, a controlling cam, each of said link members being arranged in duplicate, one on each side of a plane intersecting said control elements, a crank on said shaft, and a hook-shaped link pivotally connected to duplicate link members at a point between said duplicate link members and intermediate the pivot points thereon and extending over one of the duplicate link members and being pivotally connected to said shaft crank.

17. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a crank movable with each piston set, a pair of link members pivoted to each crank arm, one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer end of the point of connection of said link members, a controlling cam, each of said link members being arranged in duplicate, one on each side of a plane intersecting said control elements, a crank on said shaft, and a hook-shaped link pivotally connected to duplicate link members at a point between said duplicate link members and intermediate the pivot points thereon and extending over one of the duplicate link members and being pivotally connected to said shaft crank, the outer edges of

said link members being arranged to provide a recess for permitting the movement of said hook-shaped link in a path internally of the line connecting the pivot points on which said control elements are mounted.

18. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a crank connected to each set of pistons and mounted upon said shaft for free movement upon the axis thereof, means providing an internal cam surface, a plurality of control elements movable along said surface, pivotally connected pairs of duplicate sets of link members serving to mount said control elements, the link member of each set being disposed on opposite sides of the central plane of said control elements, one set of link members in each pair being connected to one arm of one of said cranks, a pivot pin extending between the link members of one of said sets, a link mounted on said pivot pin and extending laterally of one link member in one of said sets, and means for connecting said link to said shaft.

19. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a crank connected to each set of pistons and mounted upon said shaft for free movement upon the axis thereof, means providing an internal cam surface, a plurality of control elements movable along said surface, pivotally connected pairs of duplicate sets of link members serving to mount said control elements, the link member of each set being disposed on opposite sides of the central plane of said control elements, one set of link members in each pair being connected to one arm of one of said cranks, a pivot pin extending between the link members of one of said sets, a hook-shaped link mounted on said pivot pin and extending laterally of one link member in one of said sets, and means for connecting said link to said shaft, said link members being arranged to allow the movement of the laterally extending portion of said hook-shaped link in a path intersecting a line connecting the points at which adjacent control elements are mounted.

20. In a machine of the character described, in combination, a rotatable shaft, an annular cylinder, a plurality of sets of pistons arranged to rotate within said cylinder and to move angularly with respect to each other, a crank connected to each set of pistons and mounted upon said shaft for free movement upon the axis thereof, means providing an internal cam surface, a plurality of control elements movable along said surface, pivotally connected pairs of dupli-

cate sets of link members serving to mount said control elements, the link member of each set being disposed on opposite sides of the central plane of said control elements, one set of link members in each pair being connected to one arm of one of said cranks, a pivot pin extending between the link members of one of said sets, a hook-shaped link mounted on said pivot pin and extending laterally of one link member in one of said sets, and means for connecting said link to said shaft, said link members being arranged to allow the movement of the laterally extending portion of said hook-shaped link in a path intersecting a line connecting the points at which adjacent control elements are mounted, the outer edges of certain of said link members being displaced inwardly between their ends to provide space for the movement of said hook-shaped link.

21. In a mechanism of the character described, a plurality of cranks arranged for angular movement and relative reciprocation on a single axis, a plurality of control elements, link-work connecting said cranks and said control elements, said link-work being arranged in the shape of a star and including link arms extending externally and diversely from each crank arm at a point internal of the control elements to adjacent control elements, respectively, two link arms, each of which extends to a different crank arm, being pivotally connected at each control element, and means to connect said link-work with a rotatable member.

22. In a mechanism of the character described, in combination, a rotatable shaft, a plurality of cranks arranged to rotate about a single axis and to move angularly with respect to each other, a plurality of control elements, a controlling cam, means including pivoted link-work for connecting said cranks one to another, said link-work including link members each pivotally connected with a link member from another crank, one of said control elements being mounted on said link-work at a point adjacent each of the latter connections, the length of each link member between the pivot points thereon being greater than the distance from the axis of a crank to the pivot point thereon, and means to connect said link-work to said shaft.

23. In a mechanism of the character described, in combination, a rotatable shaft, a plurality of cranks arranged to rotate about a single axis and to move angularly with respect to each other, a plurality of control elements, a controlling cam, means including pivoted link-work for connecting said cranks one to another, said link-work including link members each pivotally connected with a link member from another crank, one of said control elements being mounted on said link-work at a point adjacent each of the

latter connections, the length of each link member between the pivot points thereon being greater than the distance from the axis of a crank to the pivot point thereon, a crank on said shaft, and means to connect said link-work to said shaft, the last-mentioned means including a link pivotally connected to one of said link members at a point intermediate its pivotal connection with one of said plurality of cranks and its pivotal connection with another link member.

24. In a mechanism of the character described, a pair of crank members adapted to rotate about a single axis at relatively varying periodic speeds, such that the speed of rotation of one crank is accelerating while the speed of rotation of the other crank is decelerating and vice versa, each of said crank members having oppositely disposed arms, link-work connecting said arms, control elements pivotally carried at points in said link-work intermediate adjacent arms, a controlling cam for said control elements, a rotatable member, a crank thereon, and a link pivoted to said latter crank and pivotally connected to the aforesaid link-work at a point between the point of connection of said link-work to a crank arm and the point at which one of the pairs of control elements which are proximate to said crank arm is mounted on said link-work.

25. In mechanism of the character described, a plurality of cranks arranged for angular movement and relative reciprocation on a single axis, a plurality of control elements, link-work connecting said cranks and said control elements, said link-work being arranged in the shape of a star and including link arms extending externally and diversely from each crank arm at a point internal of the control elements to adjacent control elements, respectively, two link arms, each of which extends to a different crank arm, being pivotally connected at each control element, and means pivotally mounted on said link-work intermediate a control element and a crank arm to connect said link-work with a rotatable member.

26. In a mechanism of the character described, a plurality of crank arms movable on a common axis, a similar number of elements movable in a course external to said crank arms and each disposed intermediate to two adjacent crank arms, a pair of link members connecting each external element with one adjacent crank arm, and a pair of link members connecting each external element with the other adjacent crank arm, a pin extending through each external element, a sleeve rotatably mounted on each of said pins and providing a bearing for the respective external element, the ends of each sleeve extending beyond the sides of the external element and the ends of each pin extending beyond the ends of the sleeve, means rotatably

mounted on each crank arm and providing two link-mounting portions beyond each side of the crank arm, one pair of links from each external element to a crank arm being secured on the mounting portions adjacent the crank arms and to the ends of the sleeve at the external element and the other pair of links from each external element to a crank arm being secured to the end-mounting portions at the crank arm and to the ends of the pin at the external element.

27. In a machine of the character described, a rotatable shaft, an annular cylinder, a plurality of sets of pistons, a crank movable with each piston set, a pair of link members pivoted to each crank arm, the link members of each pair being pivotally connected with each other and one of the link members of each pair being pivotally connected to a link member forming one of a pair connected to an adjacent crank arm, control elements carried at the outer ends of said link members, a controlling cam, a crank on said shaft, and a link pivoted to said latter crank and pivoted to one of the aforesaid link members at a point within an angle having its vertex on the axis of said shaft and its side intersecting the pivot points of one of said link members.

In testimony whereof I affix my signature.
CARL E. TRUBE.

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