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DIFFERENTIAL

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Fig. 1,

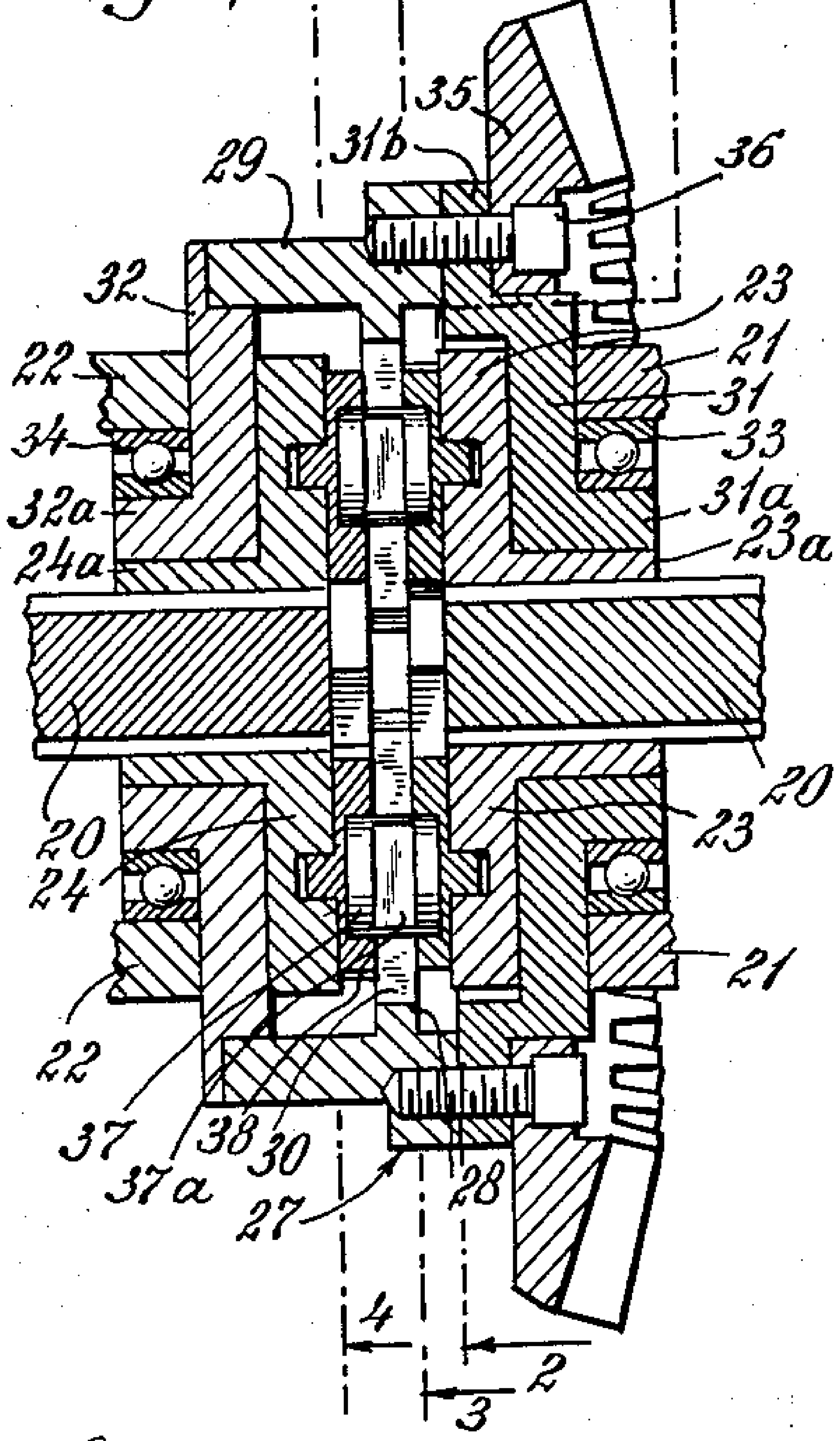


Fig. 2,

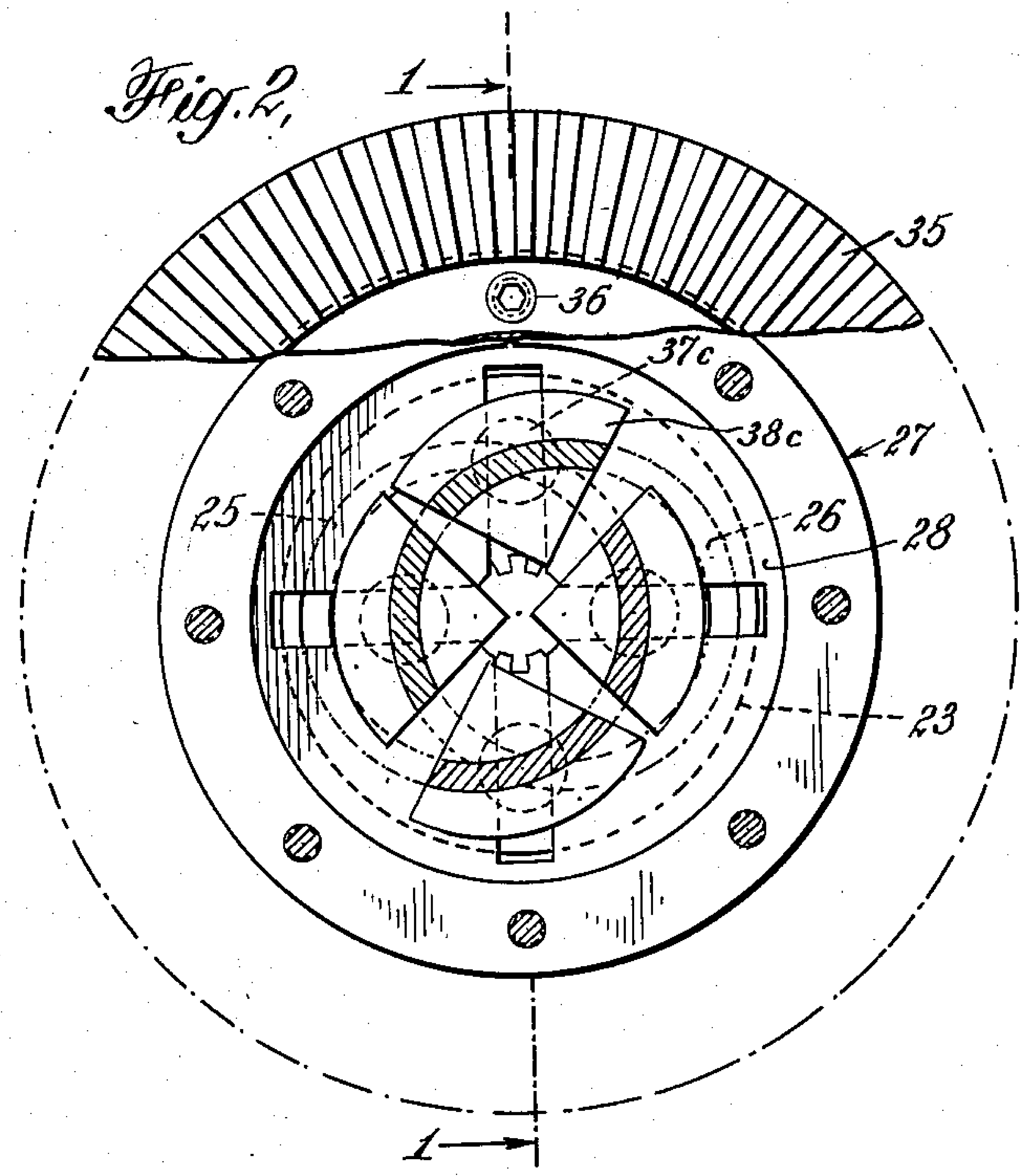


Fig. 3,

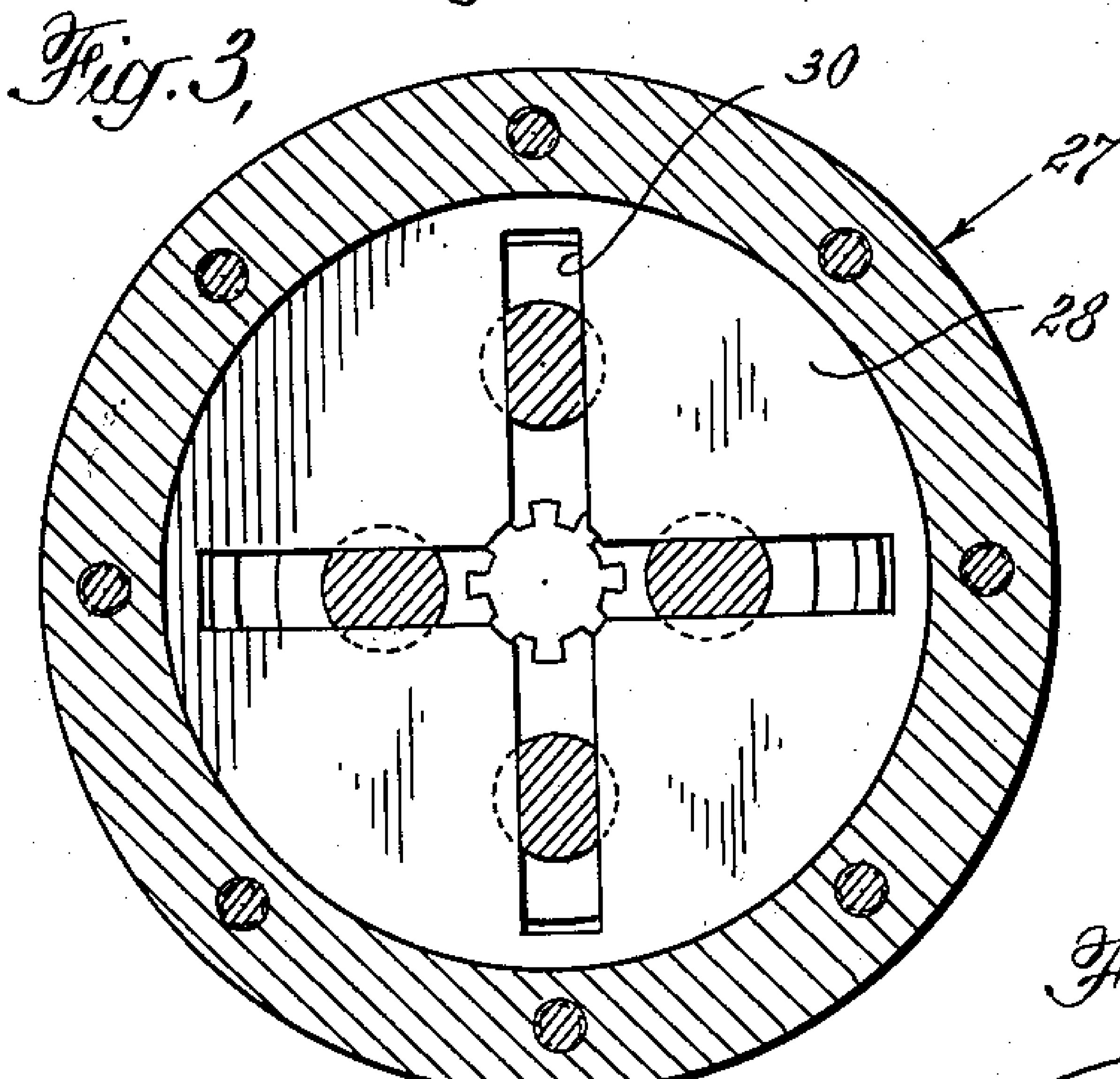


Fig. 4,

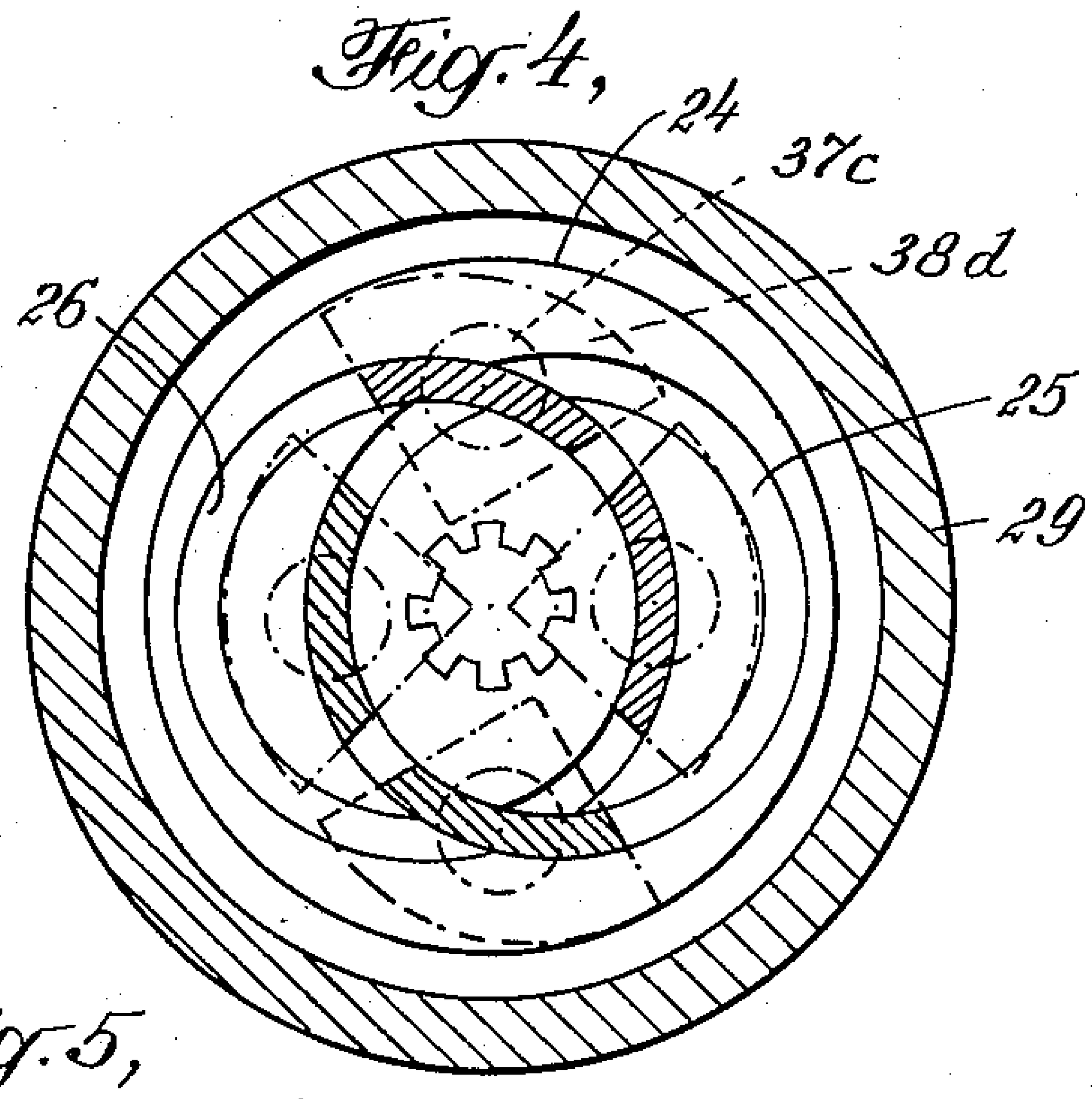
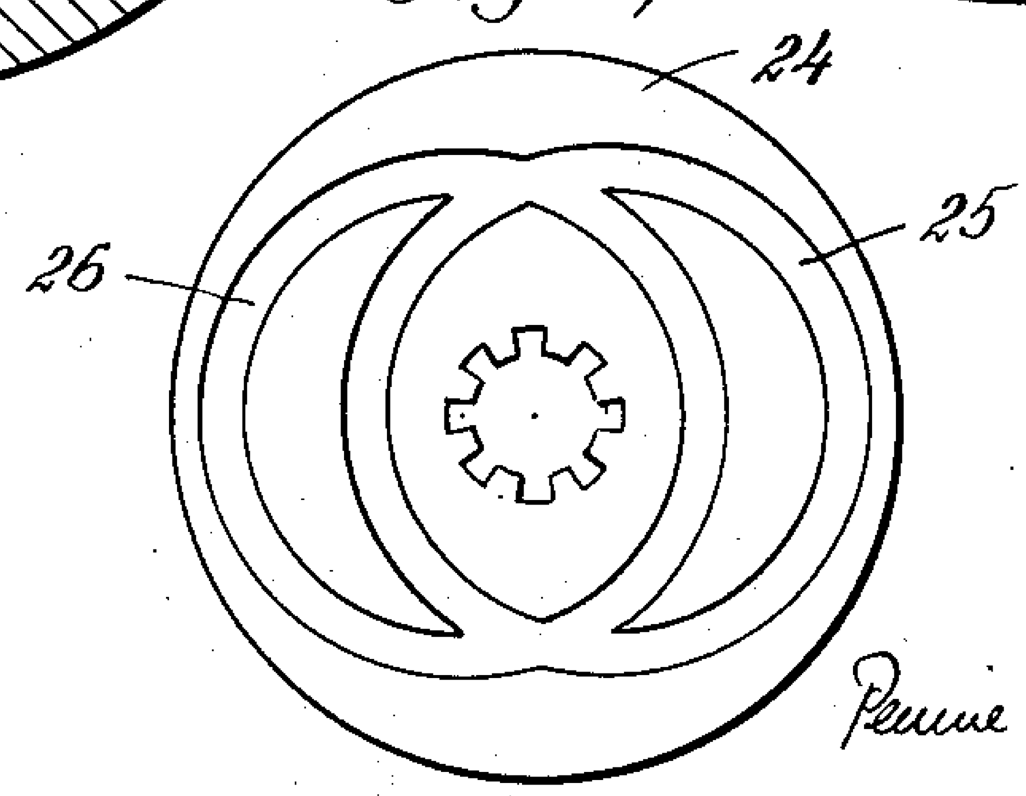


Fig. 5,



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DIFFERENTIAL

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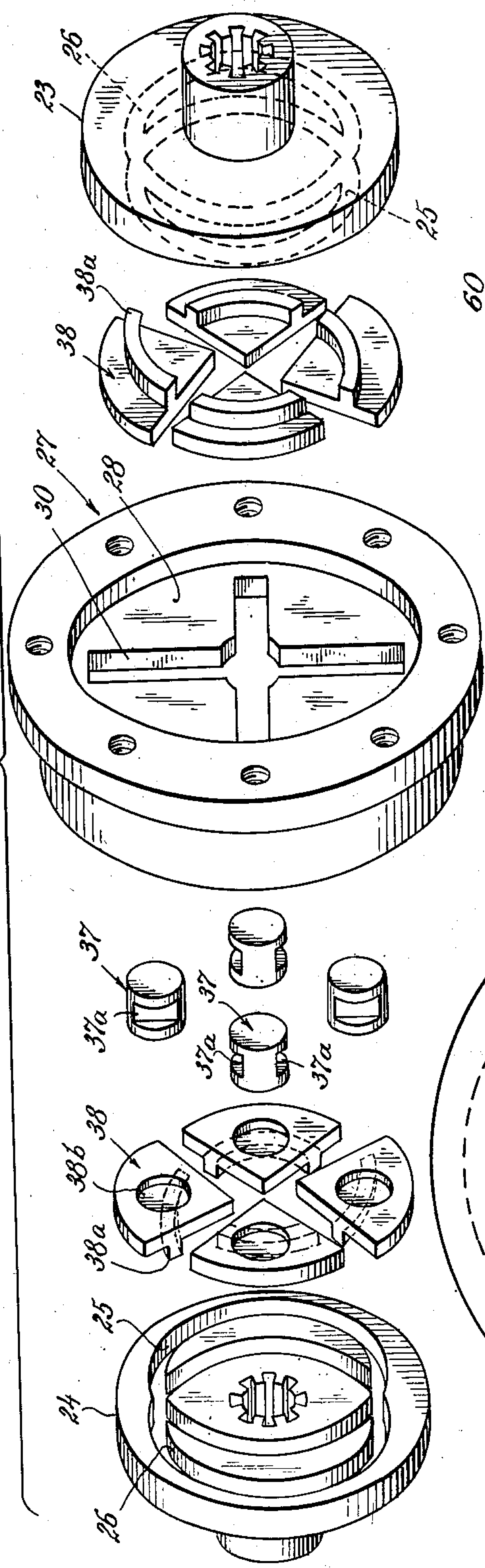

Fig. 6.

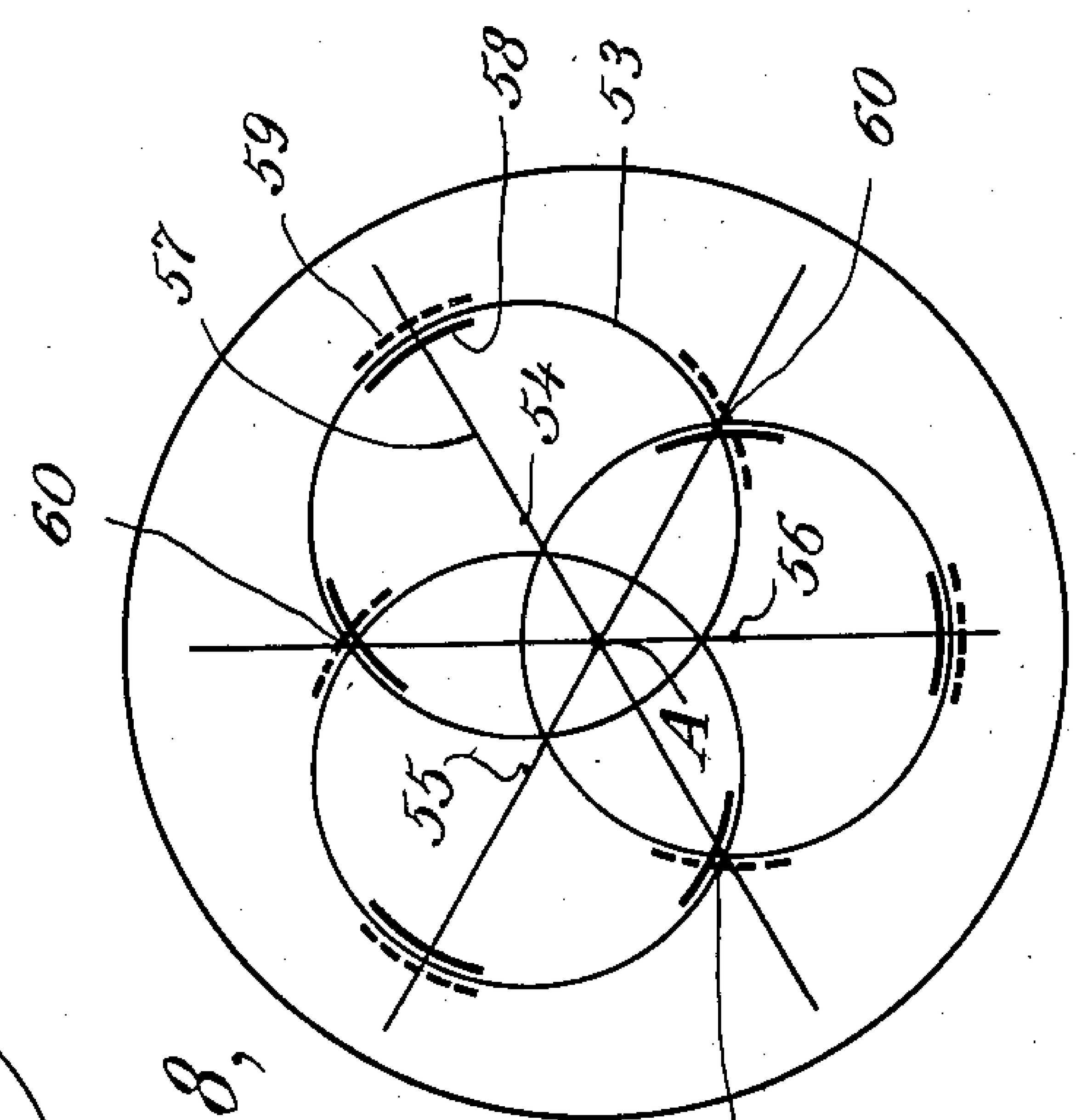

Fig. 8.

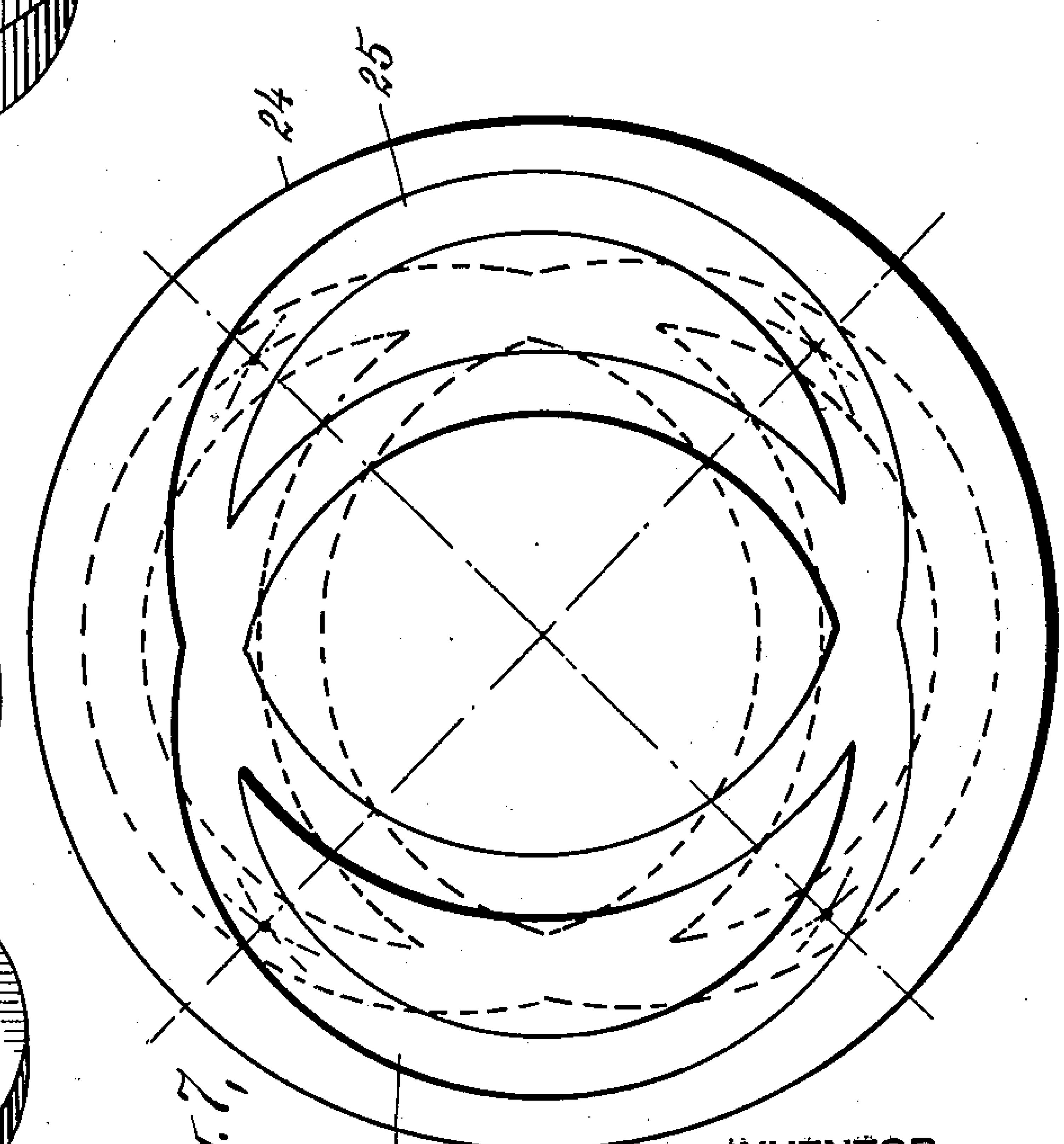

Fig. 7.

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Fig. 9,

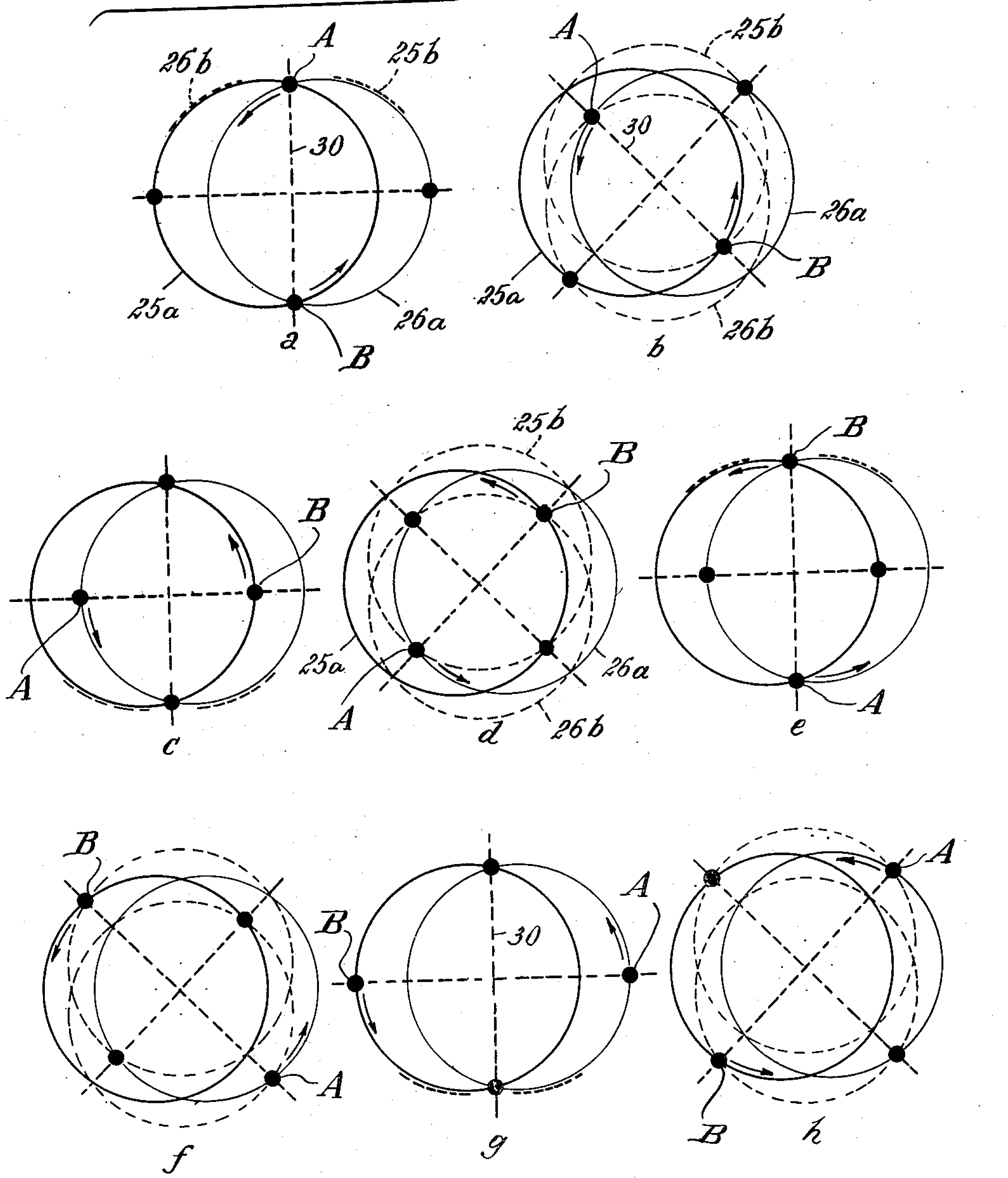

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Fig. 10.

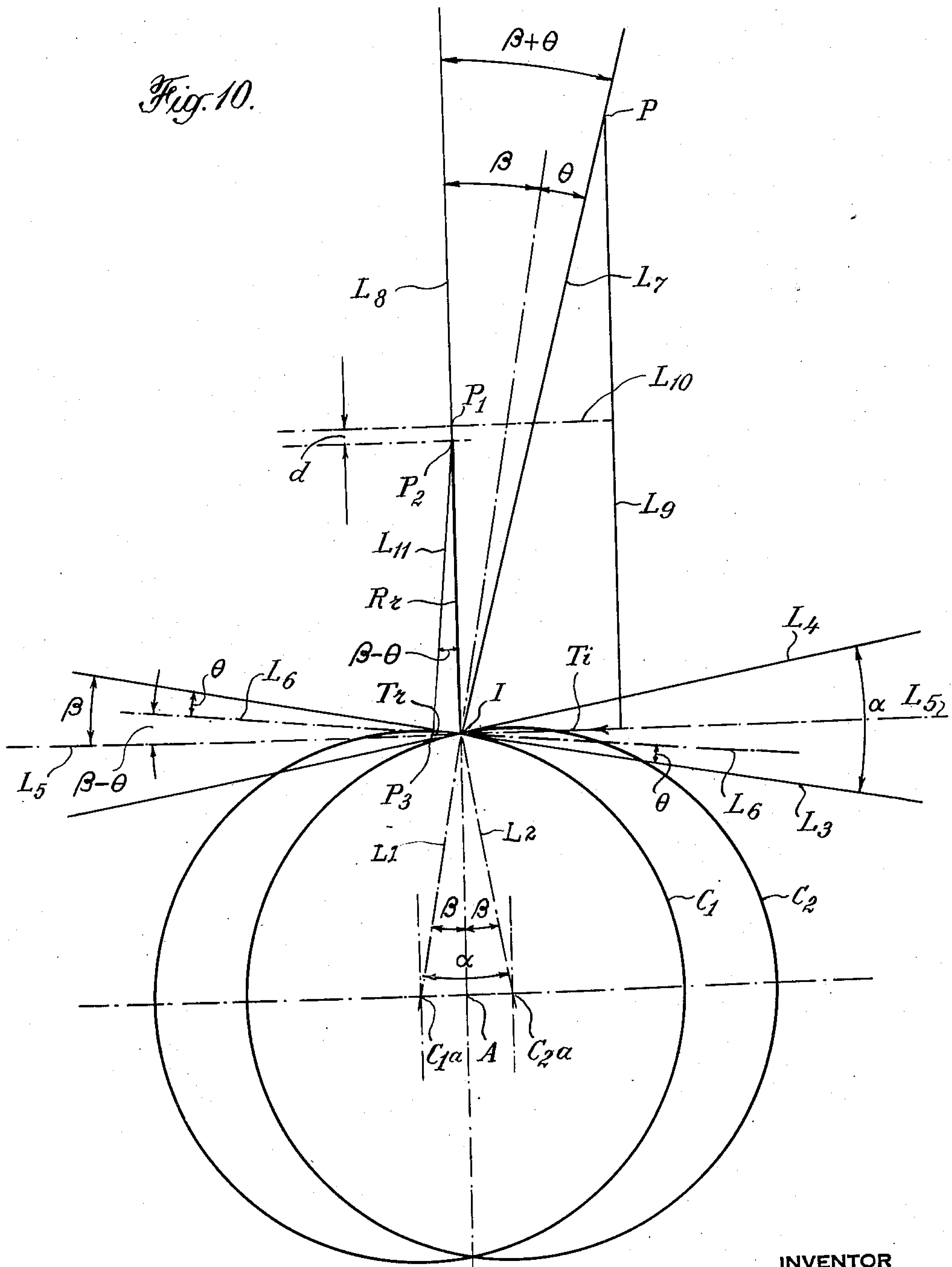

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Fig. 11

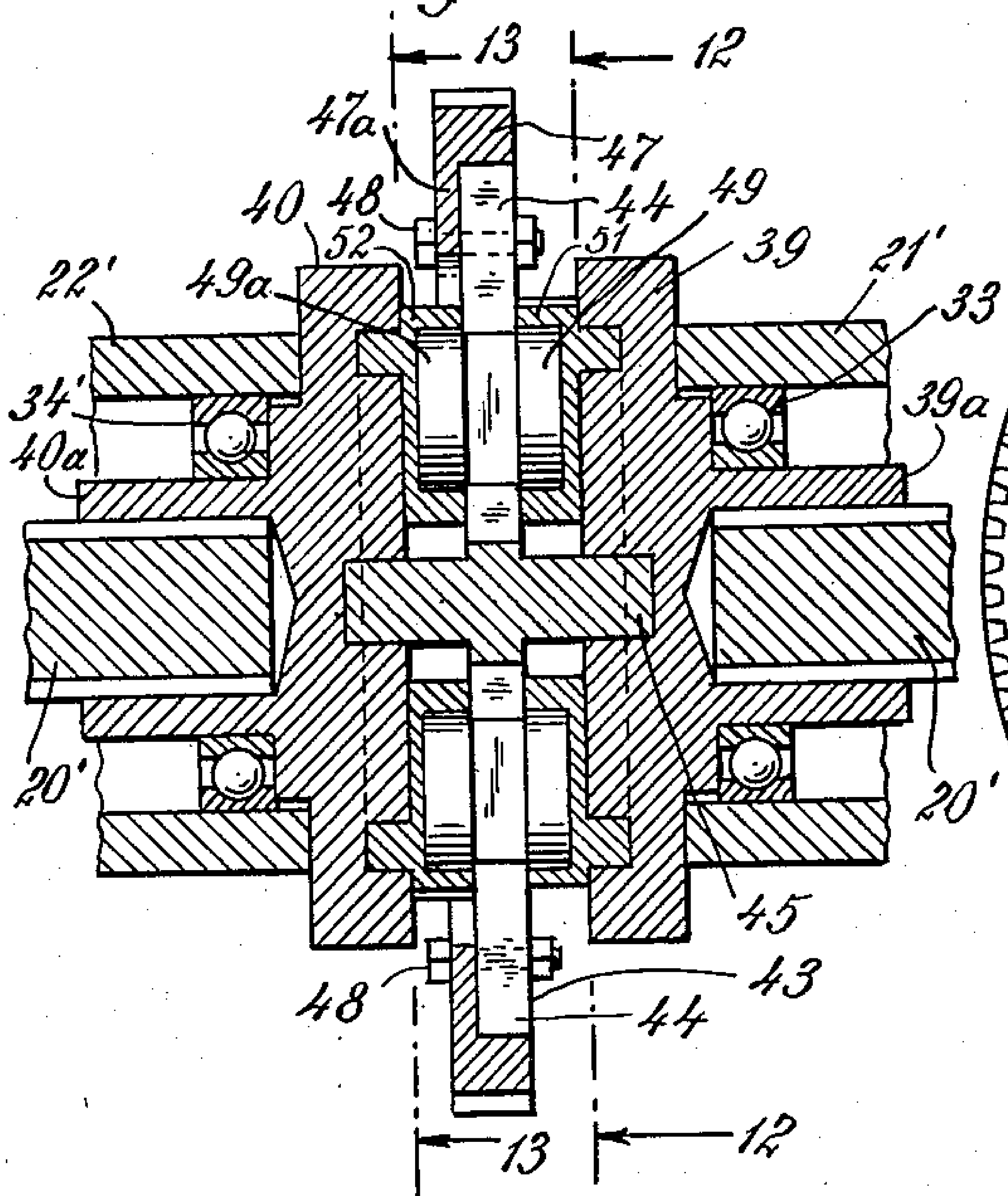


Fig. 12,

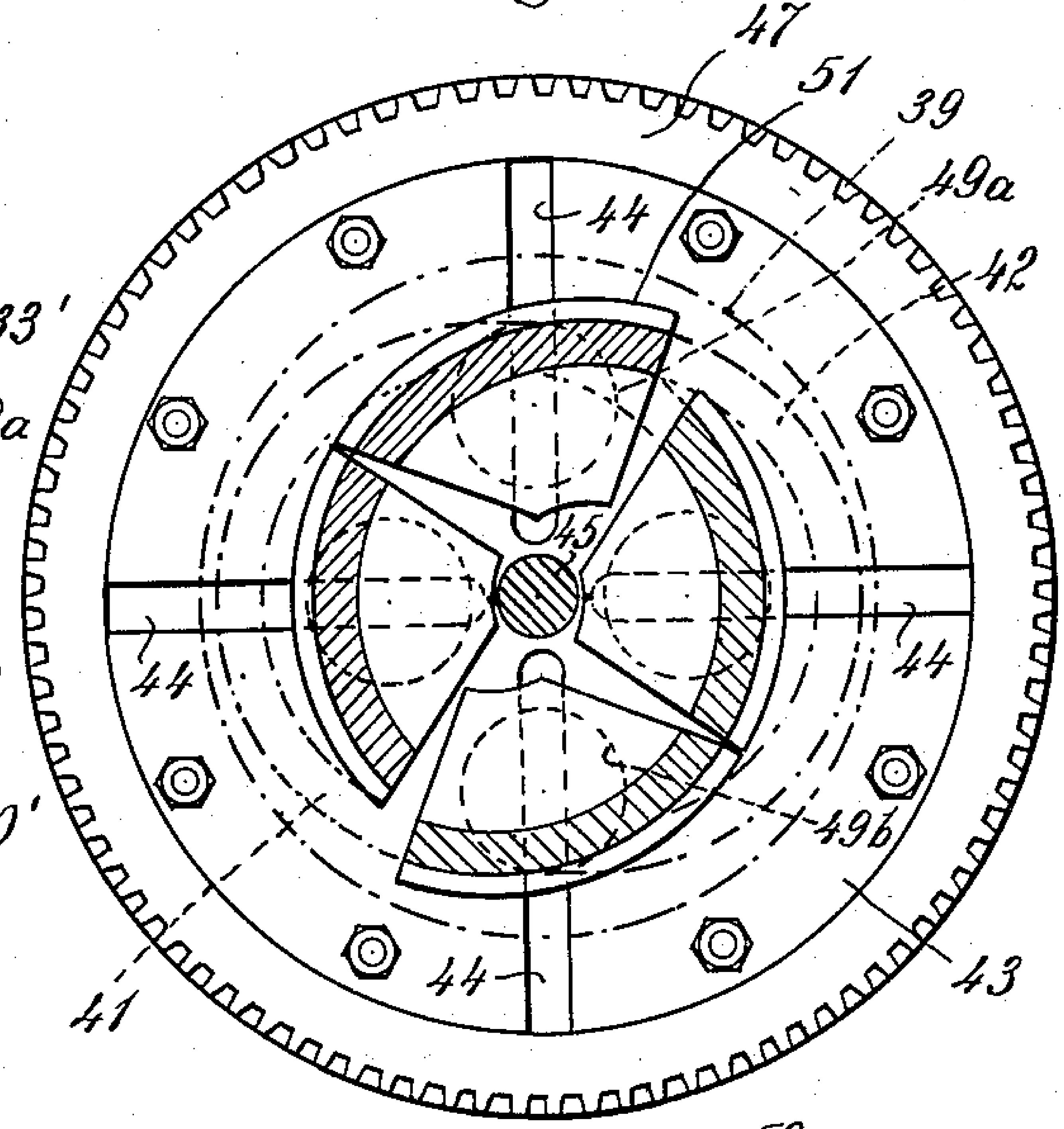


Fig. 14,

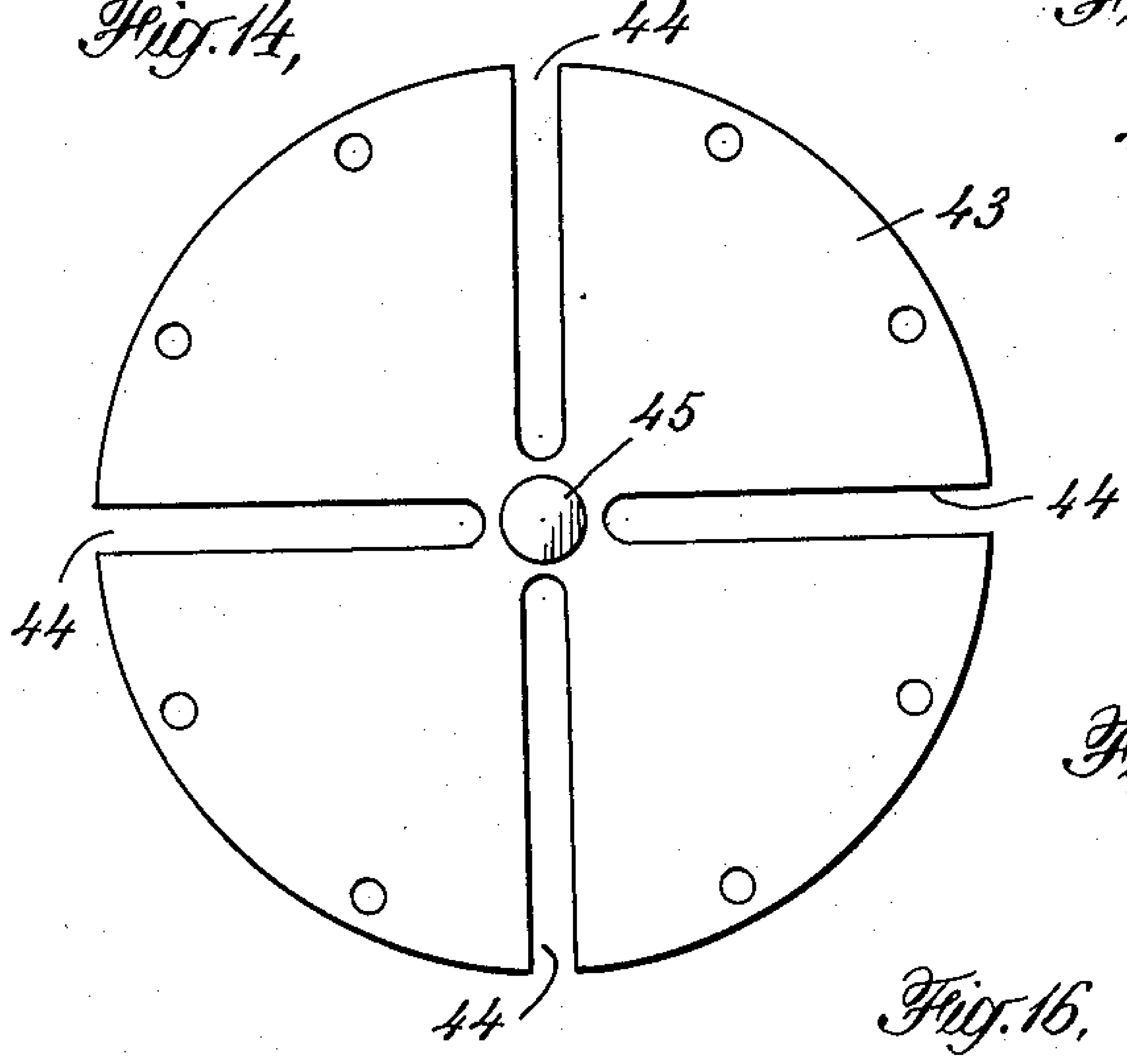


Fig. 13,

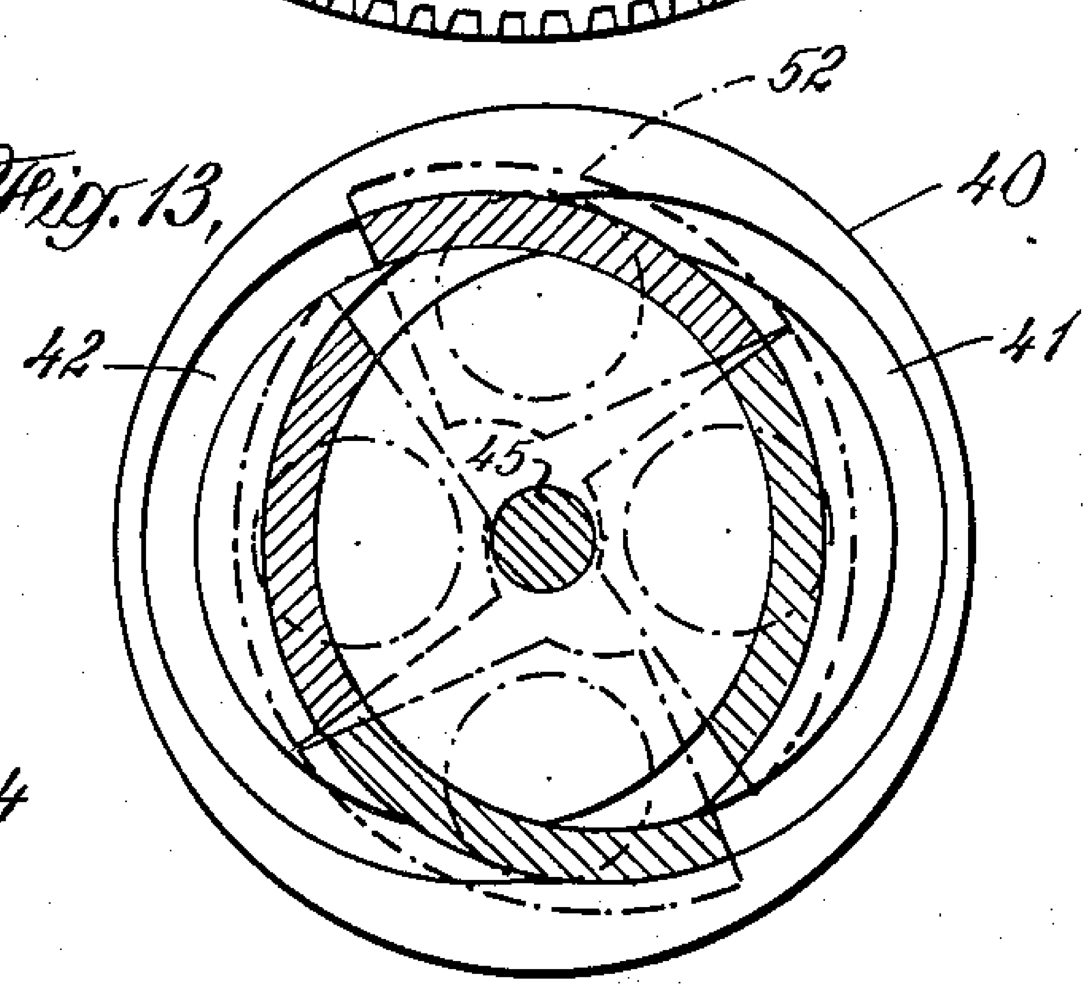


Fig. 15,

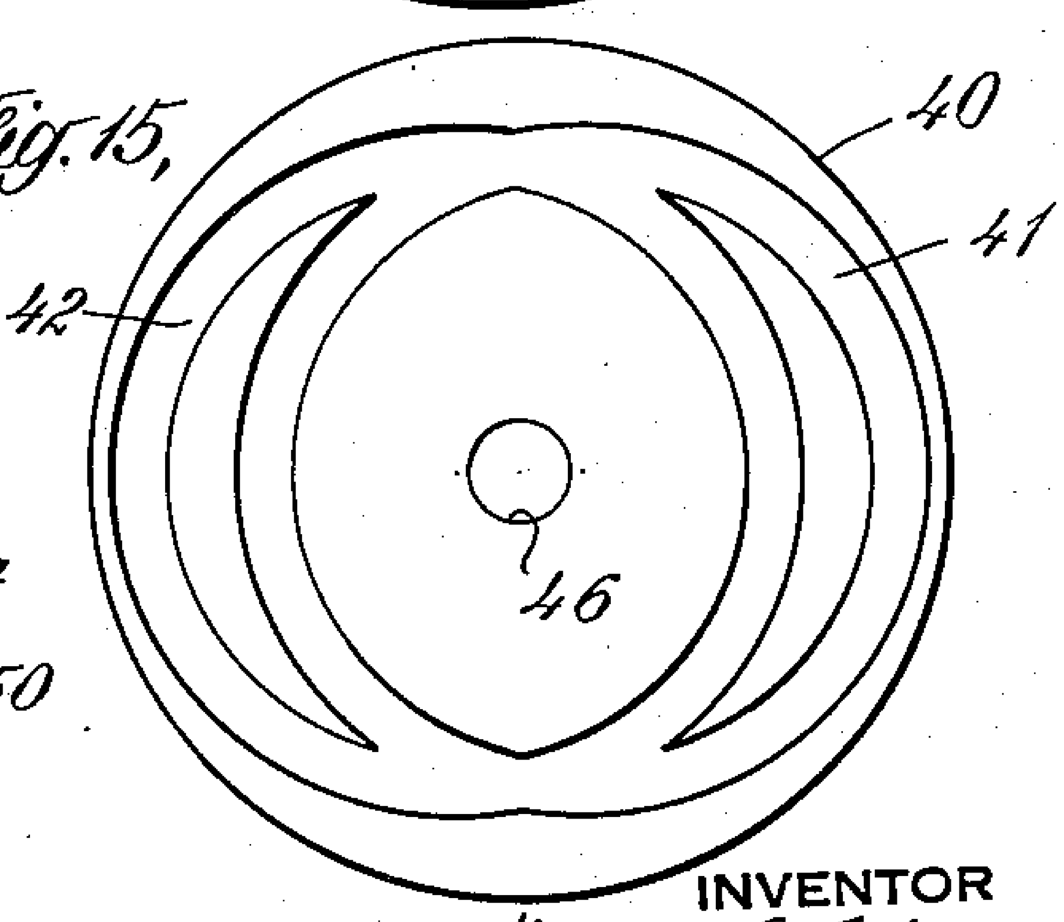


Fig. 16,

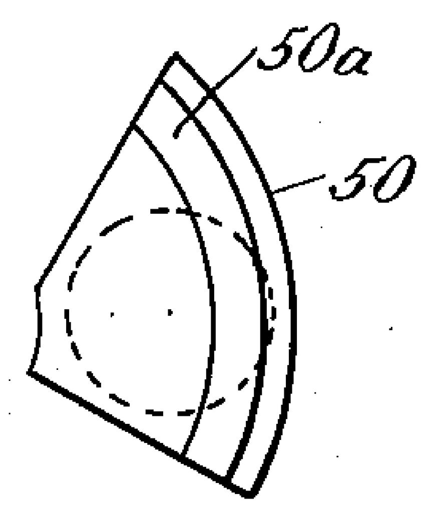
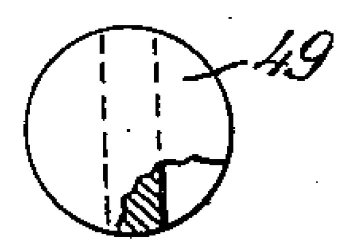


Fig. 17,



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UNITED STATES PATENT OFFICE

2,624,213

DIFFERENTIAL

Donald E. Schott, Flushing, N. Y.

Application December 1, 1951, Serial No. 259,433

12 Claims. (Cl. 74—650)

1

This invention relates to torque distributors, commonly referred to as differentials, and is concerned more particularly with a novel differential, which affords numerous advantages over similar devices as heretofore constructed.

The new differential is simple in construction and it is inexpensive to manufacture, because it does not include any gears and can be made without the use of special machinery. It provides a useful torque output on either driven member, independent of the load on the other, and operates in that manner in both directions of rotation. Also, it provides a free differentiating action, when the direction of power transmission through it is reversed as, for example, in an automobile, which is coasting, with the wheels driving the engine. The differential provides a positive drive at all times without excessive backlash and does not operate as a friction device. All operating stresses occur as radial, tensile, or compressive stresses within the driven members, and such stresses are not transmitted to or carried by bearings, and no thrust loads are produced. In its preferred form, the differential is symmetrical in construction and operation, so that it is dynamically balanced at all positions and speeds.

While the new differential may be used for numerous purposes, it affords special advantages, when employed in automotive vehicles. An embodiment of the differential suitable for such use will, accordingly, be illustrated and described in detail for purposes of explanation.

The automotive form of the new differential comprises a pair of like driven members connected to the aligned axial shafts of the vehicle and lying spaced apart. The members may have the form of discs, and the opposed faces of the discs are provided with a plurality of intersecting circular grooves. The grooves in the two discs are all of the same radius, and the centers of curvature of the grooves in each disc are equally spaced from and equiangularly spaced about the center of the disc. Each disc is provided with at least two such grooves and may have three or more. As discs with two grooves are suitable for most purposes, that construction is preferred.

A driving member, which is preferably of disc form, lies between the grooved faces of the driven members and has a plurality of angularly spaced radial slots. The number of slots in the driving member is the same as the number of grooves in a driven member or twice the number of grooves, the latter arrangement being preferred. A slide

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is mounted in each slot in the driving member for movement lengthwise of the slot, and each slide has ends projecting at opposite sides of the driving member. Between the driving member and each driven member, there is a set of connectors, one for each slide, and each connector is mounted for rocking movement on the end of a slide and has an arcuate rib entering a groove in the adjacent driven member. The arrangement of the connectors relative to the driven members is such that each slide lying in alignment with aligned intersections of grooves in the two discs engages a pair of connectors, which have ribs entering non-registering grooves in the two driven members. The driving member is driven from a prime mover in any convenient manner and, for this purpose, may carry a gear encircling its periphery. The driven members are connected to the driven shafts, preferably by being provided with hubs splined to the shafts.

For a better understanding of the invention, reference may be made to the accompanying drawings in which:

Fig. 1 is a longitudinal section through one form of the new differential on the line 1—1 of Fig. 2;

Figs. 2, 3, and 4 are transverse sectional views on the lines 2—2, 3—3, and 4—4, respectively, of Fig. 1;

Fig. 5 is an elevational view showing the grooves in one driven member;

Fig. 6 is an exploded perspective view of certain parts of the new differential shown in Fig. 1;

Fig. 7 is a diagrammatic elevational view showing the relationship of the grooves in the driven members, when one member has been rotated 90° from the position shown in Fig. 5;

Fig. 8 is a diagrammatic elevational view, showing a driven member having three grooves;

Fig. 9 is a series of diagrams illustrating the operation of the device;

Fig. 10 is a diagram showing the resolution of forces involved in the functioning of the differential;

Fig. 11 is a view similar to Fig. 1 showing a modified form of the differential;

Figs. 12 and 13 are sectional views on the lines 12—12, 13—13, respectively, of Fig. 11;

Figs. 14 and 15 are elevational views of the driving member and a driven member, respectively, of the differential shown in Fig. 11;

Fig. 16 is a view in elevation of one of the connectors of the differential of Fig. 11; and

Fig. 17 is a view, partly in elevation and partly in section, of a slide used in the differential of Fig. 11.

The differential illustrated in Fig. 1 is suitable for use in an automobile having aligned axle shafts 20 within an axle housing shown as made of two parts 21, 22, and it includes a pair of driven members 23, 24 of identical construction. The members have the form of discs provided with hubs 23a, 24a splined to respective shafts 20 and a plurality of intersecting circular grooves are formed in the face of each disc. The grooves in the discs are all of the same radius and the centers of curvature of the grooves are equally spaced from and equiangularly spaced about the common axis of the discs. The discs illustrated are provided with two grooves and the centers of curvature of the grooves in a disc are, accordingly, 180° apart and thus lie on a diameter of the disc at equal distances on opposite sides of the axis thereof. The grooves in the two discs are designated 25, 26, and, when the driven members in the assembled differential lie with the centers of curvature of their grooves on a line and the assembly is viewed from one end, the grooves 25 and 26 of one disc are in registry with the grooves 26 and 25, respectively, of the other disc.

The driven members are rotated by a driving member 27, which is coaxial with the driven members and has the form of a plate 28 having a cylindrical rim 29. The plate lies between the opposed faces of the discs of the driven members and it is provided with a plurality of angularly spaced radial slots 30. The plate has the same number of slots as the number of grooves in a disc or has twice as many slots as there are grooves, the latter arrangement being preferred. In the construction shown, the plate 28 has four slots 30 spaced 90° apart and the slots are open to each other at the axis of the driving member and terminate short of the rim 29 thereon.

A supporting member 31 of disc form having a hub 31a is mounted with its hub encircling the hub 23a of driven member 23, and a generally similar supporting member 32 having a hub 32a is mounted with its hub encircling hub 24a of driven member 2 4. Anti-friction bearings 33, 34 are interposed between hubs 31a, 32a, respectively, and the parts 21, 22 of the axle housing. The member 31 is provided with an offset peripheral flange 31b abutting one end of the rim 29 of the driving member, and a bevel ring gear 35 is secured to the flange by screws 36 passing through the web of the gear and the flange into the adjacent end of the rim 29 on the driving member. The other end of the rim 29 is seated in a peripheral channel in the outer edge of member 32.

A slide 37 is mounted in each slot 30 in the driving plate and each slide has the form of a cylindrical pin provided with flats 37a engaging the walls of its slot. The ends of each slide project on opposite sides of plate 28 of the driving member.

A set of connectors 38 of quadrant form lie between each driven member and the driving member, and each set is made up of a connector for each slide. Each connector is provided on one face with an arcuate rib 38a entering a circular groove in the adjacent driven member, and the other face of the connector is formed with a circular socket 38b receiving a projecting end of a slide 37. Of the four connectors in a set, two adjacent connectors have ribs entering one groove in the adjacent driven member and the ribs of the other two connectors enter the other

groove. The connectors are mounted on the slides in such fashion that each slide, which lies in line with aligned intersections of grooves in the two driven members, is engaged with a pair of connectors mounted for sliding movement in non-registering grooves in the respective members. This arrangement will be understood from Figs. 2 and 4, in which the centers of curvature of the grooves in the two driven members are shown as lying on a horizontal line through the common axis of rotation of the members. Slide 37c lies in line with the aligned upper intersections of the grooves in the two members, and connector 38c, mounted on one end of the slide, has a rib entering groove 26 in driven member 23. Connector 38d, mounted on the other end of slide 37c, has a rib entering groove 26 in driven member 24, the grooves 26 in the two members being cut of registry with each other.

The driving member of the differential may be rotated by power applied thereto in any convenient manner as, for example, the driving member may have a rim formed as a pulley and be driven by a belt, or the rim may have sprocket teeth and be driven by a chain. For automotive purposes, power is transmitted from the propeller shaft of the vehicle to the differential through gearing, including the driving gear 35.

In the operation of the differential, gear 35, driving member 27, and the supporting members 31, 32 rotate as a unit about the common axis of shafts 20. In this rotation of the driving member, it carries the slides 37 with it, and those slides, such as slide 37c, which lie in line with aligned intersections of grooves in the driven members, apply power to the driven members tending to rotate them. If both driven members are unrestrained, the members rotate with the slides and connectors and the latter remain stationary in their slots and grooves, respectively. If one driven member is restrained, a differentiating action takes place, which is made clear in Fig. 9.

In the eight diagrams in Fig. 9, the circular grooves of the two members are illustrated as they would appear, if viewed from the outer end of member 24. The grooves in member 24 are shown in full lines and designated 25a, 26a, and the grooves in member 23 are shown in dotted lines designated 25b, 26b. The radial slots in the driven member are indicated by broken lines 30 and the slides 37 are indicated by solid circles, two of the slides lying 180° apart being marked A and B.

In Fig. 9a, the two driven members are shown with the centers of curvatures of their grooves lying on a horizontal line, so that groove 25a in member 24 is in registry with groove 26b in member 23, and groove 26a in member 24 is in registry with groove 25b in member 23. When the driven members are in the positions shown, the driving member lies with two of its slots 30 extending horizontally and the other two extending vertically and the slides A and B lie within vertical slots and in line, respectively, with aligned upper and lower intersections of the grooves in the two discs. The connector between slide A and driven member 24 has a rib entering groove 26a in member 24 and the connecting element between the slide and driven member 23 has a rib entering groove 26b in member 23, the two grooves being out of registry. Similarly, slide B is in engagement with connectors having ribs in non-registering grooves in the driven members.

Fig. 9b shows what occurs, when the driving member is rotated through an angle of 45° counterclockwise, while driven member **24** remains at rest. In such rotational movement, the slide A moves through an angle of 45° with the driving member and, at the same time, the connector on the end of the slide, which has a rib entering groove **26***a* in driven member **24** remaining at rest, moves along groove **26***a* and the slide is caused to move inwardly along its slot. During this movement of slide A, the connector between the slide and member **23** has moved along groove **26***b* of member **23** and has caused member **23** to move counterclockwise through an angle of 90°. Slide B has moved in the same manner as slide A and assisted in the rotation of member **23**. In the new position of member **23**, the centers of curvature of its grooves lie on a vertical line.

Fig. 9*c* shows the relation of the two driven members, when the driving member has moved counterclockwise through an angle of 90° from its original position. In this condition of the driven members, their centers of curvature lie on a horizontal line and, while the driving member has passed through 90°, driven member **23** has been rotated through 180°. At the same time, the slides A and B have moved inwardly in their slots to their inmost positions.

When the driving member moves through another 45°, as shown in Fig. 9*d*, the driven member **23** is moved through another 90° and, when the driving member has traveled through 180°, as shown in Fig. 9*e*, the driven member **23** has been rotated through one complete turn. The two driven members **23, 24** then lie with their grooves in the same relative positions as in Fig. 9*a*, but slides A and B now lie in line, respectively, with the lower and upper intersections of the grooves in the two members. Figs. 9*f*, *g*, and *h* show the positions of the driving and driven members after further successive advances of the driving member through angles of 45° and, when the driving member is advanced 45° beyond the position shown in Fig. 9*h*, the parts assume the positions shown in Fig. 9*a*, and slides A and B again lie in line, respectively, with the aligned upper and lower intersections of the grooves in the two members. Accordingly, when driven member **24** is wholly restrained and the driving member rotates through 360°, driven member **23** is rotated through two complete turns or 720°.

The form of the differential shown in Figs. 11–17, inc., comprises a pair of like driven members **39, 40** having the form of discs provided with hubs **39***a*, **40***a* splined to respective aligned axle shafts **20′, 20′** within an axle housing made of two parts **21′ 22′**. The opposed faces of the discs are provided with a plurality of intersecting circular grooves **41, 42**, and the grooves in the discs are all of the same radius and the centers of curvature of the grooves are equally spaced from and equiangularly spaced about the common axis of the discs. An anti-friction bearing **33′** lies between hub **39***a* of driven member **39** and axle housing **21′**, and a similar anti-friction bearing **34′** lies between hub **40′** of driven member **40** and axle housing **22′**.

A driving member **43** lies between the driven members and it has the form of a disc provided with a plurality of radial slots **44**. An axial stud **45** projects from each face of the driving member and is received in a central socket **46** in the adjacent driven member. A ring gear **47**, having an internal flange **47***a*, is mounted to encircle the driving member with the flange lying against one face of the driving member, and the gear is se-

cured to the driving member by bolts **48** passing through flange **47***a* and openings through the driving member.

A slide **49**, which is similar to slide **37**, is mounted in each radial slot **44** of the driving member and has cylindrical ends projecting beyond opposite faces of the driving member. A connector **50**, which is generally of quadrant form, is mounted for rocking movement on each end of each slide, and each connector has a curved rib **50***a*, which enters one of the grooves **41, 42** in the opposed face of the adjacent driven member. Of the four connecting elements between the driving member and each driven member, two adjacent elements have ribs entering the same groove in the driven member, and the other two have ribs entering the other groove in the driven member. A slide, such as slide **49***a* (Fig. 12), which lies in line with aligned intersections of the grooves in the two driven members, engages a pair of connectors having ribs mounted for sliding movement in non-registering grooves in the respective members, as will be apparent from Figs. 12 and 13. Thus, the connector **51** mounted on slide **49***a* has a rib, which enters groove **42** in member **39**, whereas the connector **52** has a rib entering groove **42** in driven element **40**. As viewed from either end of the assembly, grooves **42** have their centers on a horizontal line through the axis of the assembly but are out of registry. The slide **49***a* lies in registry with the aligned upper intersections of the grooves in the two driven members, and the connecting elements mounted on slide **49***b*, which lies in line with the aligned lower intersections of the grooves in the two driven members, likewise engages a pair of connectors having ribs mounted in non-registering grooves in the two driven members.

The form of the differential shown in Figs. 11–17, inc., is simpler than that shown in Fig. 1, in the respect that the Fig. 11 form does not require supporting members corresponding to members **31, 32**, and the driving member **43** is of simpler construction than member **27**. The Fig. 11 form of the differential functions in the same manner as that shown in Fig. 1 and provides a differentiating action, as explained in connection with Fig. 9. In the device of Fig. 11, the connectors are formed with their ribs lying close to the curved edges of the connectors and the socket in each connector for receiving the projecting end of the slide is of relatively large diameter. The slides **49** used in the Fig. 11 device are generally similar to slides **37** but have cylindrical ends of greater diameter than the corresponding ends of slides **37**.

The diagram, Fig. 10, illustrates the resolution of forces effective in the new differential as shown in Fig. 1 to cause rotation of the driven members, when one is free to rotate and the other is restrained. In the diagram, the circles C_1, C_2 represent aligned pairs of intersecting grooves lying at the points C_{1a} and C_{2a}, respectively, which are shown as lying on a horizontal line through the common axis of rotation A of the driven members. The lines L_1 and L_2, passing through the centers of the grooves and the upper point of intersection I of the grooves, then define an angle α. The lines L_3, L_4 are tangent to grooves C_1, C_2, respectively, at the point I, and the angle between lines L_3, L_4 is angle α and is bisected into two angles β by line L_5, which is tangent at I to an imaginary circle having its center at A.

The line L_6, passing through point I, makes an angle θ with line L_3, the value of angle θ being such that tan θ equals the co-efficient of friction between the surfaces of the grooves and the ribs of the connectors sliding in the grooves. The angle between line L_5 and line L_6 is the difference between angle β and angle θ and may be referred to as angle $\beta-\theta$.

In Fig. 10, the line Ti represents the torque input applied to a slide at point I and tending to cause rotation of the assembly made up of the slide, the connectors, the driven members, etc. The line L_7 passing through point I makes an angle $\beta+\theta$ with the vertical line L_8 passing through points I and A. Line L_9 is normal to line Ti at the origin thereof and intersects line L_7 at point P. Since the slide, to which the force Ti is applied at point I, is engaged with a pair of connectors sliding in non-registering grooves in the two driven members, the force Ti is exerted with a wedging action and only half the length of line L_9 is to be considered in determining the vertical resultant R of force Ti. Accordingly, the line L_{10} has been drawn to bisect line L_9 and lies parallel to line Ti. The vertical resultant is then the length of line L_8 between point I and the point P1 of intersection of lines L_8 and L_{10}. As part of the resultant R is employed in overcoming friction, the net resultant Rr equal to the length of line L_8 between points I and P2, the point P2 lying spaced from point P1 a distance d, which is equal to the input force Ti multiplied by the co-efficient of friction, that is, tan θ. A line L_{11} drawn from point P2 and making an angle of $\beta-\theta$ with line L_8 intersects the continuation of line Ti at point P3, and the line Tr between points I and P3 represents the force tending to cause rotation of the driven member free to rotate. The force tending to cause rotation of the driven member, which is restrained, is the difference between Ti and Tr.

The mathematical formulae for determining the values of Tr and Ts are as follows:

$$(1)\qquad R=\frac{Ti}{2\tan(\beta+\theta)}$$

$$(2)\qquad Rr=R-Ti\tan\theta$$

$$(3)\qquad Tr=Rr\tan(\beta-\theta)$$

Applying the formulae to a specific differential, in which angle $\alpha=20°$, angle $\beta=10°$, the coefficient of friction of the ribs of the connectors sliding in the grooves is assumed to equal .087, so that angle $\theta=5°$, and Ti is assumed to equal unity, the value of R, as determined by Formula 1, equals 1.83. The net vertical resultant Rr tending to effect rotation of the driven member free to rotate is found by Formula 2 to equal $1.83-.087=1.74$. The force Tr tending to cause rotation of the driven member free to rotate, as determined by Formula 2, then equals $1.74\times.087=.15$. The force Ts tending to cause rotation of the restrained driven member then equals $Ti-Tr=1-.15=.85$. The force Ts thus bears the relation of

$$\frac{.85}{.15}$$

to the force Tr, that is,

$$\frac{Ts}{Tr}=\frac{.85}{.15}=5.67$$

or the force Ts tending to cause rotation of the restrained driven member is 5.6 times the force Tr tending to cause rotation of the driven member free to rotate.

It can be determined by calculation from the

formulae that, with a given coefficient of friction and corresponding angle θ, variations in angle α produce different average proportions of the input torque available for absorption by the restrained and unrestrained driven members, respectively. When angle α has a value of about $90°-\theta$, the proportions of input torque available for absorption by the two members is approximately the same, disregarding frictional losses, so that the new differential, in which such an angle α is employed, operates in the same manner as a conventional differential. It will also be evident from the formulae that angle β must always equal or exceed θ and thus angle α must always equal or exceed 2θ. If angle β equals θ, all the input torque is applied to the restrained driven member and none to the unrestrained driven member. As it is desirable, particularly in automotive use, that the part of the input torque tending to cause rotation of the restrained driven member be substantially greater than that available to cause rotation of the unrestrained driven member, the differential is best constructed with angle α greater than but approaching angle 2θ as closely as practical structural considerations permit.

The relative average proportions of the torque absorbed by the driven members can be influenced further by varying the location of the pivot centers of the slides in their connectors, either inwardly or outwardly radially relative to the ribs on the connectors, which enter the grooves in the driven members. Moving the pivot centers inwardly has the same effect as decreasing angle α, while moving the pivot centers outwardly has the opposite effect.

In the form of the differential shown in Figs. 1–6, incl., the center of the pivot socket in each connector is intersected by the center line of the arc of the rib on that connector and the diagram Fig. 10 applies to that construction. In the form of the differential shown in Figs. 11–17, incl., the center of the pivot socket in each connector lies inwardly radially from the center line of the arc of the rib. In this construction, the value of the angle β for calculating R in Formula 1 is determined as follows. An arc of a radius equal to the distance of the pivot socket on a connector from the center of curvature of the groove entered by the rib of that connector is drawn on Fig. 10 about that center of curvature, which may, for example, be center C_2a. A line is then drawn from center C_2a through the point on line L_8 intersected by the arc. The angle β then lies between the line so drawn and line L_3. As this angle is greater than the original angle formed between lines L_2 and L_8, the value of R as determined by Formula 1 will be correspondingly reduced. In Formulae 1 and 2, the value of the torque input Ti is assumed to be unity at the radius AI and will increase proportionally as its point of application moves inwardly toward point A. Also, the value of d, which equals Ti tan θ, becomes larger, so that the net resultant Rr is decreased and Tr is correspondingly decreased. In determining Tr by Formula 3, the value of β must remain constant, regardless of the location of the center of the pivot sockets in the connectors. Accordingly, moving the centers of the pivot sockets inwardly has the same effect as decreasing angle α.

The differential illustrated in Figs. 1 and 11 includes a pair of driven members, each of which has two intersecting circular grooves opening toward the driving member between the driven members, and the driving member has four radial slots. With such a construction, the differential is balanced in action, as is made clear in the diagrams, Fig. 9. The driving member transmits power to the driven members only through slides lying in line with aligned intersections of the grooves in the two driven members and through the connectors engaged by those slides, the other slides and connectors being ineffective. When the driven members lie with their grooves in registry as shown in Fig. 9*a*, the driving member transmits power to the driven members through the two slides A and B in the vertical slots in the driving member and the slides in the horizontal slots are idle. When the driven member shown in Fig. 9 as free to rotate has moved angularly, so that the line through the centers of its grooves is displaced from the line through the centers of the grooves of the restrained driven member, power is transmitted through all four slides and their related connectors from the driving member to the driven member, since, with the driven members relatively displaced as described, all four slides lie in line with aligned intersections of the grooves in the two members. This is apparent from Fig. 9*b*, in which the driven members are relatively displaced through 90°.

It will be apparent from the foregoing that, if the driven members have two grooves and the driving member has two slots, the slots must be at right angles to each other, in order that the differential will function. However, with such a driving member, a condition will occur, when the slide in one slot is transmitting power from the driving member to the driven member free to rotate and the slide in the other slot is not transmitting power. At this instant, power will be wholly transmitted through a single slide and its connectors and the action will be unbalanced. If the driving member were provided with two slots lying aligned, the differential would not function, because the slides would be ineffective to transmit power, when aligned with the lines through the centers of the grooves of the driven members. If the driving member in a differential of the two-groove type were provided with three slots, the same unbalanced action described above in connection with a driving member having two slots would occur at certain stages in the operation. Accordingly, while the differential will function, when the driving member has only as many slots as there are grooves in each driven member or less than twice the number of grooves, balanced operation requires that the driving member have twice as many slots as there are grooves in a driven member.

Instead of providing each driven member with two intersecting circular grooves, it is possible to employ three grooves and the action occurring in such a differential is diagrammatically illustrated in Fig. 8. In that figure, the circles 53 represent aligned grooves in the two driven members and the centers 54, 55, 56 of the grooves lie equally spaced from and equiangularly spaced about the axis of rotation A. The lines 57 radiating from axis A represent slots in the driving member. The solid arcuate lines 58 represent connectors of a set lying between the driving member and one driven member, and the dotted arcuate lines 59 represent connectors of the set lying between the driving member and the other driven member. The connectors 58, 59 are connected to slides, and, at each of the aligned intersections 60 of the grooves in the two driven members, the slide is connected to a connector 58 and a connector 59 having ribs entering non-registering grooves in the two driven members.

The three-groove differential shown in Fig. 8 functions in the same manner as the other forms of differential except that, as a minimum and as shown in Fig. 8, three slides are effective to transmit power from the driving member to the driven members. With such a division of the load, the slides and connectors may be of somewhat lighter construction than would be necessary in a two-groove differential for carrying the same load. If desired, the driven members may have more than three grooves and, in a form of the differential in which the driven members have four grooves, the centers of the grooves are 90° apart and equally spaced from and about the axis of rotation. Any advantage to be gained by using driven members with more than three grooves would probably be overbalanced by the disadvantage of the complexities of the construction and, for most purposes, the differential has driven members provided with two grooves, as shown in Figs. 1 and 11.

I claim:

1. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having a plurality of intersecting circular grooves in its face opposed to the other member, the grooves all having the same radius and the centers of curvature of all the grooves being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member coaxial with and between the driven members and having a plurality of angularly spaced radial slots, the number of slots being at least equal to the number of grooves in a driven member, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

2. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having a plurality of intersecting circular grooves in its face opposed to the other member, the grooves all having the same radius and the centers of curvature of all the grooves being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member coaxial with and between the driven members and having a plurality of equiangularly spaced radial slots, the number of slots being twice the number of grooves in a driven member, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

3. In a differential, the combination of a pair of driven members, each member including a disc having a plurality of intersecting circular

grooves in one face and the members being mounted for coaxial rotation with their grooved faces opposed, the grooves in the discs being all of the same radius and the centers of curvature of the grooves all being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member coaxial with and between the discs and having a plurality of angularly spaced radial slots, the number of slots being at least equal to the number of grooves in a driven member, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in the grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

4. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having a flat radial face formed with a pair of intersecting circular grooves, the grooves in the members being all of the same radius and the centers of curvature of the grooves in each member lying on a diameter of the member on opposite sides of the axis of rotation with all said centers lying equally spaced from said axis, the members being disposed with their grooved faces opposed, a driving member coaxial with and between the driven members and having four equiangularly spaced radial slots, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

5. In a differential, the combinaion of a pair of driven members mounted for coaxial rotation, each member having a flat radial face formed with three intersecting circular grooves, the grooves in the member being all of the same radius and all the centers of curvature of the grooves in the members being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member coaxial with and between the driven members and having six equiangularly spaced radial slots, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

6. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having means for attachment to an element to be driven thereby, each member having a surface formed with a plurality of intersecting circular grooves lying in a plane normal to the axis of rotation of the member, the members having the same number of grooves and being disposed with the grooves in one member opening toward those in the other, all the grooves in the members being of the same radius and having their centers of curvature equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member between the driven members, means for supporting the driving member for coaxial rotation with the driven members, the driving member having a plurality of angularly spaced radial slots, the number of slots being at least equal to the number of grooves in a driven member, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

7. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member including a disc and an axial hub, the members being mounted with the faces of their discs opposed to each other and said faces each being formed with a plurality of intersecting circular grooves, the grooves all having the same radius and the centers of curvature of all the grooves lying equally spaced from and equiangularly spaced about the axis of rotation of the driven members, a driving member between the driven members, means for supporting the driving member for coaxial rotation with the driven members, the driving member having a plurality of angularly spaced radial slots, the number of slots being at least equal to the number of grooves in a driven member, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

8. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member including a disc and an axial hub, the members being mounted with the faces of their discs opposed to each other and said faces each being formed with a plurality of intersecting circular grooves, the grooves all having the same radius and the centers of curvature of all the grooves lying equally spaced from and equiangularly spaced about the axis of rotation of the driven members, a driving member between the driven members, a supporting member mounted for coaxial rotation with the driven members and engaging the driving member and

supporting it for coaxial rotation with the driven members, the driving member having a plurality of angularly spaced radial slots, the number of slots being at least equal to the number of grooves in a driven member, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

9. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having a central socket and a plurality of intersecting circular grooves in its face opposed to the other member, the grooves all having the same radius and the centers of curvature of all the grooves being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member between the driven members, the driving member having projections from its opposite sides received in the sockets in the driven members and supporting the driving member for coaxial rotation with the driven members, the driving member having a plurality of angularly spaced radial slots, the number of slots being at least equal to the number of grooves in a driven member, a slide mounted in each slot and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

10. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having a plurality of intersecting circular grooves in its face opposed to the other member, the grooves all having the same radius and the centers of curvature of all the grooves being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member coaxial with and between the driven members and having a plurality of angularly spaced radial slots, the number of slots being at least equal to the number of grooves in a driven member, means attached to the driving member for rotating it, a slide mounted in each slot in the driving member and having portions exposed on opposite sides of the driving member, and a set of connectors between each driven member and the driving member and mounted for sliding movement in grooves in the adjacent driven member, each set consisting of a connector for each slide connected to the slide for rocking movement relative thereto, each slide lying in line with aligned intersections of grooves in the two driven members being connected to a pair of connectors mounted for sliding movement in non-registering grooves in the respective members.

11. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having a plurality of intersecting circular grooves in its face opposed to the other member, the grooves all having the same radius and the centers of curvature of all the grooves being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member mounted for rotation coaxially with and between the driven members and having a plurality of angularly spaced radial slots extending through it, the number of slots being at least equal to the number of grooves in a driven member, and a plurality of assemblies, one for each slot in the driving member, having portions mounted in respective slots for sliding movement, each assembly having other parts slidably entering a pair of grooves, one in each driven member, each groove receiving at least one part of an assembly and each assembly lying in line with aligned intersections of grooves in the two driven members having parts entering non-registering grooves, one in each member, in the respective driven members.

12. In a differential, the combination of a pair of driven members mounted for coaxial rotation, each member having a plurality of intersecting circular grooves in its face opposed to the other member, the grooves all having the same radius and the centers of curvature of all the grooves being equally spaced from and equiangularly spaced about the common axis of rotation of the members, a driving member mounted for rotation coaxially with and between the driven members and having a plurality of angularly spaced radial slots extending through it, the number of slots being twice the number of grooves in a driven member, and a plurality of assemblies, one for each slot in the driving member, having portions mounted in respective slots for sliding movement, each assembly having other parts slidably entering a pair of grooves, one in each driven member, each groove receiving at least one part of an assembly and each assembly lying in line with aligned intersections of grooves in the two driven members having parts entering non-registering grooves, one in each member, in the respective driven members.

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