PATENT SPECIFICATION

DRAWINGS ATTACHED

1,007,484

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Index at acceptance:—G3 T(A5T, A5X); H2 A(1B2D, 1B2J, 1B2K, 1B2M, 4X, 15X)
Int. Cl.:—G 04 c//H 02 k

COMPLETE SPECIFICATION

Tuning Fork Clock

ERRATUM

SPECIFICATION No. 1,007,484
Amendment No. 1

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Page 1, line 2, *after* "which" *insert* "the"
THE PATENT OFFICE
24th November 1966

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corresponding expensive.

Tuning fork clocks in which tuning forks are used instead of balance wheels or pen-
20 dulums have already been described in British Patent Specification No. 854196. However, in such tuning fork clocks, the oscillatory motion of the tuning fork is converted to a rotary motion by mechanical means and the
25 hands are moved by the rotary motion. Thus, they have the defect that the mechanism for converting such oscillatory motion of the tuning fork to a rotary motion is complicated to make and they are, in consequence, costly.
30 Furthermore, there is suggested in British Patent Specification No. 660584 a magnetic escapement mechanism, wherein a permanent magnet is attached to the forward end of an oscillator and a rotary wheel (escapement
35 wheel), made of magnetic material and having magnetically unsymmetrical undulated magnetic tracks, is arranged between the magnetic poles of the permanent magnet, so that the rotary wheel may be driven by the oscillator.
40 This arrangement has not been used in practice, probably because the torque generated by the oscillating magnet acting on the unsymmetrical

a desired direction and at least at synchronous speed; the magnet poles and the inner and 60 outer magnetic elements of the disc being so arranged that, when the fork is oscillating and the disc rotating at synchronous speed, the poles and elements co-operate to maintain the rotation of the disc, in the desired direction, 65 at synchronous speed.

A main object of the present invention is to provide at a low cost a high precision tuning fork clock wherein the oscillatory motion of a tuning fork is converted to a rotary motion 70 by a simple mechanism.

Another object of the present invention is to make it easy to manufacture rotary discs having magnetically symmetrical magnetic elements. 75

A further object of the present invention is to provide a tuning fork clock having a mechanism which can simply adjust the frequency of a mechanical oscillator.

The present invention will now be explained 80 with reference to the accompanying drawings in which:

Figure 1 is a perspective view of an embodi-

[Price 4s. 6d.]

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COMPLETE SPECIFICATION

Tuning Fork Clock

We, NIHON DENKI TOKEI KABUSHIKI KAISHA, a corporation organized under the laws of Japan, of 346 Naka-Meguro 2-chome, Meguro-ku, Tokyo, Japan, do hereby declare
5 the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
10 This invention relates to a tuning fork clock.

Balance wheel and pendulum mechanisms have long been used as timekeeping oscillators. However, if such mechanisms are to oscillate
15 sufficiently uniformly for use in precision clocks, they must be precisely made and are correspondingly expensive.

Tuning fork clocks in which tuning forks are used instead of balance wheels or pen-
20 dulums have already been described in British Patent Specification No. 854196. However, in such tuning fork clocks, the oscillatory motion of the tuning fork is converted to a rotary motion by mechanical means and the
25 hands are moved by the rotary motion. Thus, they have the defect that the mechanism for converting such oscillatory motion of the tuning fork to a rotary motion is complicated to make and they are, in consequence, costly.
30 Furthermore, there is suggested in British Patent Specification No. 660584 a magnetic escapement mechanism, wherein a permanent magnet is attached to the forward end of an oscillator and a rotary wheel (escapement
35 wheel), made of magnetic material and having magnetically unsymmetrical undulated magnetic tracks, is arranged between the magnetic poles of the permanent magnet, so that the rotary wheel may be driven by the oscillator.
40 This arrangement has not been used in practice, probably because the torque generated by the oscillating magnet acting on the unsymmetrical

tracks is so small that it is difficult to keep the wheel and magnet in synchronism. In addition, it is difficult to manufacture rotary 45 wheels having magnetically unsymmetrical undulated magnetic paths.

According to this invention a tuning fork clock comprises a tuning fork having a permanent magnet at the end of at least one 50 of its tines; means for driving the tuning fork; a rotary disc having inner radial spoke-like magnetic elements and outer projecting radial magnetic elements, the disc being rotatably disposed between the magnet poles; a clock 55 time train mechanism connected to the rotary disc; and a starting mechanism for starting rotation of the clock mechanism and disc in a desired direction and at least at synchronous speed; the magnet poles and the inner and 60 outer magnetic elements of the disc being so arranged that, when the fork is oscillating and the disc rotating at synchronous speed, the poles and elements co-operate to maintain the rotation of the disc, in the desired direction, 65 at synchronous speed.

A main object of the present invention is to provide at a low cost a high precision tuning fork clock wherein the oscillatory motion of a tuning fork is converted to a rotary motion 70 by a simple mechanism.

Another object of the present invention is to make it easy to manufacture rotary discs having magnetically symmetrical magnetic elements. 75

A further object of the present invention is to provide a tuning fork clock having a mechanism which can simply adjust the frequency of a mechanical oscillator.

The present invention will now be explained 80 with reference to the accompanying drawings in which:

Figure 1 is a perspective view of an embodi-

[Price 4s. 6d.]

ment of a tuning fork clock according to the present invention;

Figure 2 is an enlarged perspective view showing the relative positions of the magnetic poles of a magnet and a rotary disc;

Figure 3 is a wiring diagram of an electric means for driving a tuning fork;

Figures 4 to 10 are plan views each showing the relative positions of magnetic poles and the magnetic elements of a rotary disc.

Figure 11 is an explanatory plan view of the magnetic elements of a rotary disc.

Figure 12 is a view for explaining the operation of an adjusting device.

In Figures 1 and 3, 1 is an electric means for driving a tuning fork, 2 is a tuning fork, 3 is a driving coil, 4 is a feedback coil, 5 is a transistor, 6 is a dry battery, 7 is a resistor, 8 is a capacitor and 9 and 9^1 are magnetic cores.

The operation of the electric driving means will now be explained.

When the dry battery is connected to the circuit, owing to a base current flowing to the resistor 7, a collector current will flow through the driving coil 3. This collector current causes the driving coil 3 to attract the tuning fork 2 outward. The feedback coil 4 picks up a voltage related to the motion of the tuning fork and is so connected as to feed the voltage back to the base-emitter circuit of the transistor 5 to decrease the base current and, therefore, the collector current. The tuning fork 2 is thus maintained in continuous oscillation.

In Figure 1, 10 is a support for the tuning fork 2, 11 and 11^1 are ring-shaped permanent magnets fixed to the free ends of the tuning fork 2. A rotary disc 12, having inner and outer radial magnetic elements disposed within the paths of the poles N and S of the magnets 11 and 11^1, is connected only magnetically with the free ends of the tuning fork; the disc is fixed to a shaft 13. 14 is a pinion fixed also to the shaft 13 and meshing with a gear 16 fixed to a shaft 15. 17 is a pinion fixed to the shaft 15. A seconds hand 20 is rotated by a seconds hand gear 18. An hour hand 22 and a minute hand 21 are rotated through train 19. 23 is a starting device for starting the clock.

24 is an adjusting plate, so arranged that its edge is near the poles of the magnet 11, fixed to one end of the shaft 25. The shaft 25 is carried in a bush 26 and has a pinion 27 fixed to the other end. 28 is a spring set between the bush 26 and pinion 27, to bring mating cone bearing parts of the adjusting plate 24 and the bush 26 into close contact with each other. 29 is a nut to fix the bush 26 to a base plate 30. 31 is a worm gear meshing with the pinion 27. 32 is a worm gear shaft carried by parts 33 and 33^1, attached to the base plate 30. 34 is an indicating wheel fixed to the shaft 32.

The operation of the clock described will now be explained. When electric energy is fed to the electric driving means from the electric battery 6, the tuning fork 2 will begin to oscillate. If the starting device 23 is operated to temporarily rotate the rotary disc 12 at a speed greater than synchronous speed, the oscillatory motion of the tuning fork 2 will be transmitted as a rotary motion to the rotary disc 12 and, as its speed falls to the synchronous speed, a normal operating state will set in. The disc 12 then continues to be rotated by the tuning fork 2 at synchronous speed, so long as energy is supplied to the driving means. The manner in which oscillatory motion of the tuning fork 2 is transmitted as a rotary motion to the rotary disc 12 will now be described, referring to Figures 4 to 10.

The phrase "the motion of the magnetic poles N and S" or any phrase meaning it, as used in the following specification, is to simplify the explanation and includes the simple oscillatory motion of the tuning fork 2 having the magnets 11 and 11^1 fixed to the forked ends.

In Figures 4 to 10, the double hatched rectangle represents, in cross-section, the gap between the poles N and S of one magnet, in relation to the rotary disc 12. Although two magnets 11 and 11^1 are shown in Figure 1, only one will be considered in what follows; the other magnet acts in a similar manner.

When the tuning fork oscillates, the magnet 11 carried by one tine of the fork will oscillate along the path AA^1, about the point O as origin, with a maximum amplitude less than AA^1. The disc 12 is made of a soft magnetic material so that radial elements, such as 35 and 38, and connecting elements, such as 36 and 37, being magnetic will be attracted into the gap. The various elements are symmetrically disposed with respect to the radial axes such as OQ_2 and OP_2; thus, if the pole path AA^1 coincides with one such radial axis, as shown in Figures 4 and 5, the magnetic elements will be symmetrically attracted into the gap and the resultant torque on the disc will be zero. A slight misalignment between the pole path AA^1 and a radial axis will, however, produce a resultant clockwise or anticlockwise torque on the disc, according as the radial axis lies to the left or the right of the pole path, and the disc will rotate accordingly, through a small angle, until the axis and the pole path become aligned.

In use it is necessary to subject the disc 12, and therefore the shaft 13, to a substantially continuous torque in one desired direction so as to drive the time train and other movable parts, via the pinion 14.

The fork is first set oscillating. The starting device 23 in Figure 1, is then actuated, to rotate the disc 12 in the desired direction, at a speed greater than the synchronous speed.

The magnetic elements of the disc will then be passing through the gap in, for example, a clockwise direction, as shown in Figure 6, at a speed which is decreasing towards the synchronous speed. At synchronous speed the poles and disc interact as follows. In Figure 6, the radial axis OQ_2 has been displaced by the rotation of the disc, to the right of pole path AA^1, with respect to the positions shown in Figure 4. As the magnet is moved inwardly by the oscillation of the fork, so that the gap moves towards the point A, the magnetic element 38, to the left of the pole path AA^1, will be closer to the gap than magnetic element 39, to the right of the pole path; the element 38 will thus be drawn towards the poles and a clockwise torque will be applied to the disc, maintaining its clockwise rotation.

Figure 7 shows conditions when the gap is at the limit of its travel towards the point A; the disc has moved, clockwise, so that the radial axis OP_2 is slightly to the right of the pole path AA^1. The magnet is now moving outwardly, towards the point A^1; as the gap approaches A^1, the magnetic element 41 will be closer to the poles than the element 35 and will be drawn towards them, continuing the application to the disc of a clockwise torque. As the poles and gap again reverse their direction of movement, magnetic element 43 will be drawn clockwise into the gap (Figure 8). Corresponding torques are exerted as all the radial axes OP_1, OQ_1, OP_2, OQ_2 . . . . OP_n, OQ_n, pass through the gap and clockwise rotation of the disc 12 is maintained through successive revolutions, the rotation being in step with the oscillations of the fork.

The action just described occurs, whether the disc and gap have the relative positions shown in Figure 4 or Figure 5, at the moment of starting. Furthermore, if the disc is started with an anticlockwise rotation, it will continue to rotate in an anticlockwise direction.

The connecting elements, such as 36, 37, 40 and 42 will also be attracted by the poles; since, however, these parts are joined to form a continuous ring, the resulting clockwise and anticlockwise torques will always be balanced, whatever the relative positions of the poles and the disc. As these connecting elements thus contribute no rotational torque, they may all be made of non-magnetic material, without affecting the action of the device.

It is desirable to so shape the magnetic poles N and S, and the inner and outer radial magnetic elements, that the elements are attracted by the poles, as the disc rotates, sufficiently strongly and uniformly to provide a desired synchronous conversion of the oscillatory motion of the fork to a rotary motion. This end may be achieved by relating the shapes of the poles and the magnetic element as follows.

In Figure 9, the width c of each of the magnetic poles is less than the width b of each of the magnetic elements. With this arrangement, when a radial axis, such as OQ_3, is slightly displaced, by rotation of the disc to a position such as is indicated by the dashed lines, from coincidence with the pole path AA^1 (the gap being in a position such as is shown in Figure 9), there is still substantially no unsymmetrical attraction of the elements by the poles; the poles are thus not able to retard the rotation of the disc. As shown in Figure 9, the poles and gap are moving towards point A so that, by the time the disc has moved sufficiently for the poles to exert an unsymmetrical torque on the elements, element 43 will be attracted most and clockwise rotation will continue unretarded. If the width c of each magnetic pole is greater than the width b of each of the elements, a similar argument will apply. If, however, the widths b and c are equal, there will be retardation of the disc, as each radial axis passes the pole path; which is a condition preferrably avoided.

The length d of each of the magnetic poles N and S is preferrably from 1.2 to 4 times the radial width e of the connecting elements. Unless the amplitude AA^1 of motion of the magnetic poles is large, further increasing the length d will introduce a retarding torque. Thus, if, as shown in Figure 10, the amplitude of motion of the poles is insufficient in relation to their lengths d, the lower end part of each of the poles will exert an anticlockwise torque on the disc, as the gap moves from element 39 to element 35. Therefore, the length d should be determined by considering not only the magnitude of the magnetic flux but also the limiting positions which the magnets, carried by the tines of the tuning fork 2, can take up.

It has been already explained that, when the tuning fork 2 is driven and the rotary disc 12 is to be rotated thereby, the disc must first be started rotating, at a speed greater than the synchronous speed, by means of the starting device 23. Evidently, the starting device 23 must be capable of providing sufficient torque for the disc to exceed the synchronous speed.

A tuning fork, such as is used in the present invention, can be inexpensively made to have a rate at least as constant as that of more costly balance wheel or pendulum devices. Furthermore, the rotary disc, for converting the oscillatory motion of the fork into rotary motion for driving, for example, indicating hands, is less costly to produce than hitherto known motion converters.

The precision of a tuning fork clock, such as has been described herein, can be increased by providing means for adjusting the oscillation frequency of the fork. A suitable device is illustrated in Figure 2, which shows a cam-shaped plate 24 rotatably mounted in the

leakage-flux path of the poles of the magnet 11. This plate is capable of varying, to a small extent, the oscillation frequency of the fork, as the plate is rotated to bring its edge closer to or further from the poles.

Figure 12 illustrates the relationship of the plate 24 and the magnet 11 more clearly. In Figure 12(A) the plate is so oriented that its edge is closest to the poles, the magnetic coupling between the poles and the plate being a maximum; Figure 12(B) shows the edge furthest away, the coupling being a minimum. The edge of the plate may be so shaped that the oscillation frequency of the fork is linearly related to the angular position of the plate.

The angular position of the plate 24 may be adjusted accurately by means of a mechanism such as is illustrated in Figures 1 and 2 and described hereinbefore. This mechanism allows a large movement of the indicating wheel 34, relative to the movement of the plate 24; it is thus possible, by rotating the indicating wheel, to control the adjustment of the oscillation frequency of the fork very closely, over a continuous range corresponding to that between the limiting positions, of the plate 24, shown in Figure 12(A) and (B).

In a particular example, the available range of adjustment was 20 seconds per day. The gear ratio between the indicating wheel 34 and the plate 24 was such that 20 revolutions of the wheel were required to move the plate from the position shown in Figure 12(A) to that in Figure 12(B); thus one revolution of the indicating wheel corresponded to an adjustment of the rate of the clock of one second per day. If, for example, an error of 5 seconds per day is to be corrected, in such a clock, then the indicating wheel 34 can be turned five revolutions, in the appropriate direction, and the correction will be made.

The frequency adjusting device just described makes possible simple and accurate adjustment of the rate of a tuning fork clock according to this invention.

WHAT WE CLAIM IS:—

1. A tuning fork clock comprising a tuning fork having a permanent magnet at the end of at least one of its tines; means for driving the tuning fork; a rotary disc having inner radial spoke-like magnetic elements and outer projecting radial magnetic elements, the disc being rotatably disposed between the magnet poles; a clock time train mechanism connected to the rotary disc; and a starting mechanism for starting rotation of the clock mechanism and disc in a desired direction and at least at synchronous speed; the magnet poles and the inner and outer magnetic elements of the disc being so arranged that, when the fork is oscillating and the disc rotating at synchronous speed, the poles and elements co-operate to maintain the rotation of the disc, in the desired direction, at synchronous speed.

2. A clock as claimed in claim 1 wherein the inner and outer radial magnetic elements are arranged alternately and are connected together by means of a ring-shaped member concentric with the rotary disc; the ring-shaped member having a radial width as small as possible, consistant with providing necessary support for the magnetic elements.

3. A clock as claimed in claim 1 or 2, wherein there is provided means, so adjustably coupled with the leakage-flux path of at least one of said permanent magnets as to exert a retarding influence on the motion of the fork; whereby the oscillation frequency of the fork may be adjusted.

4. A clock as claimed in claim 3 wherein said means comprises a cam-shaped plate rotatably mounted in the leakage-flux path of one of the permanent magnets; the plate being so shaped that the oscillation frequency of the fork is linearly related to the angular rotation of the plate.

5. A tuning fork clock substantially as herein described, with reference to the accompanying drawings.

For the Applicants,
CARPMAELS & RANSFORD,
Chartered Patent Agents,
24, Southampton Buildings,
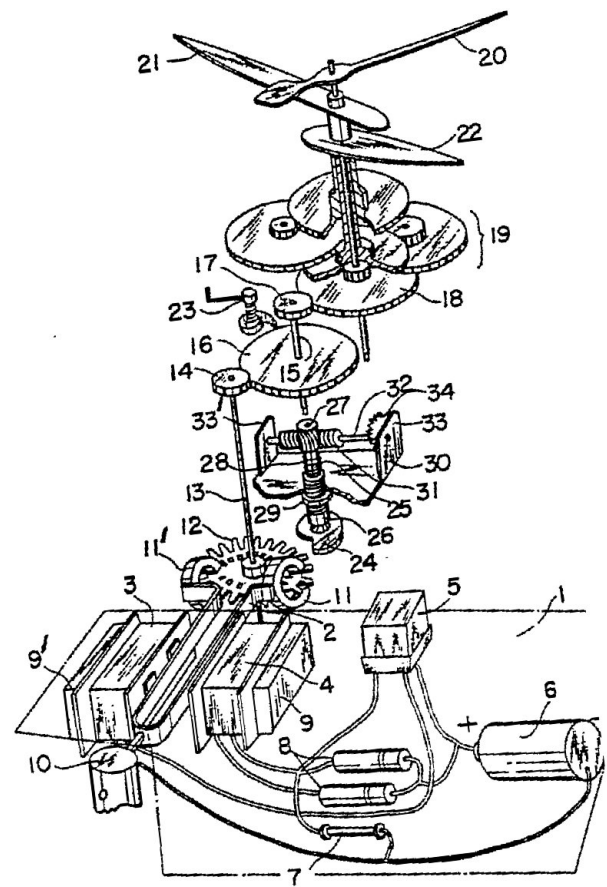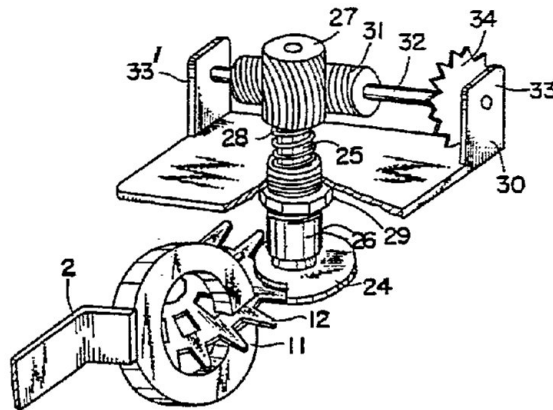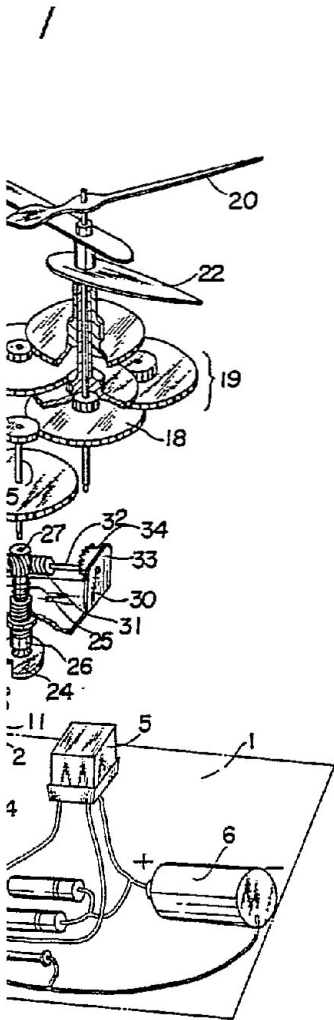Chancery Lane,
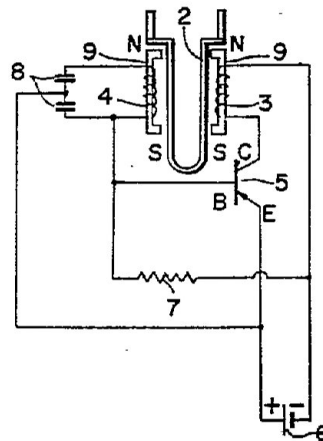London, W.C.2.

Fig. 1

Fig. 2

Fig. 3

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Sheets 1 & 2

Fig. 2

Fig. 3

Fig. 1

Fig. 4

Fig. 5

4

Fig. 6

7. 5

Fig. 7

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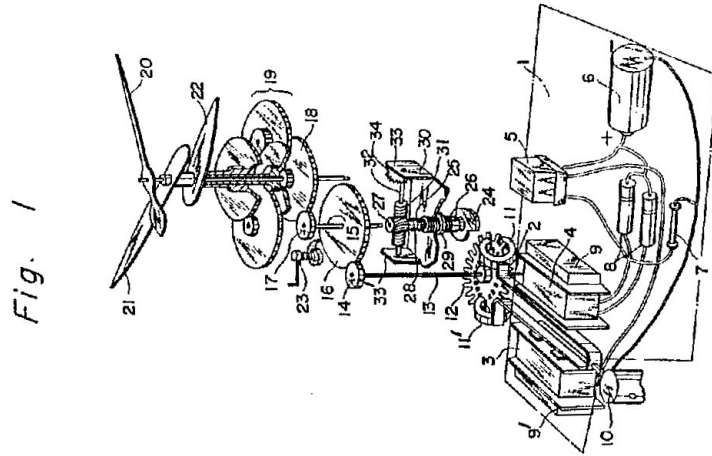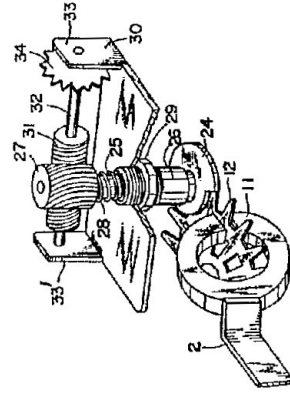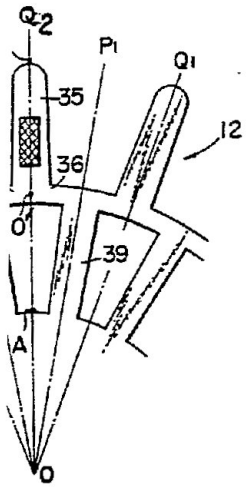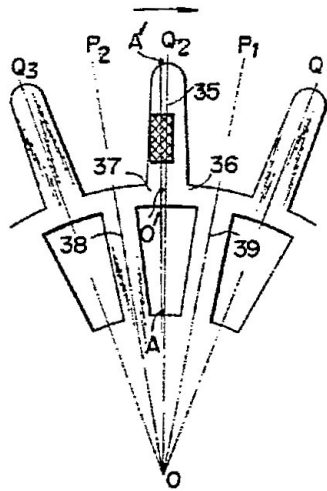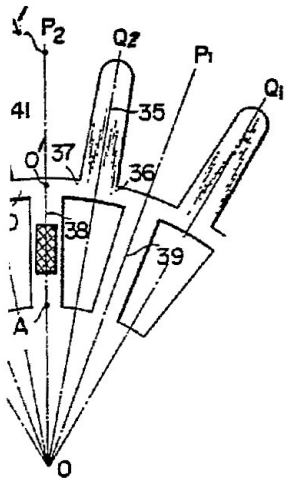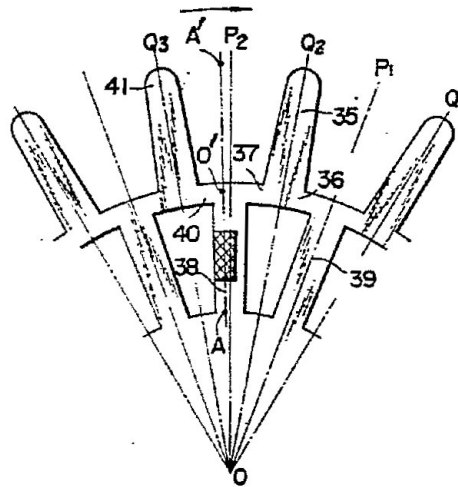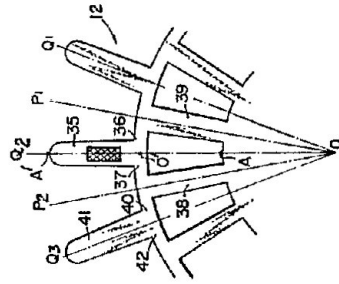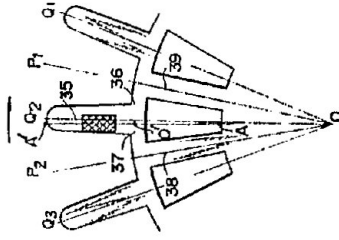
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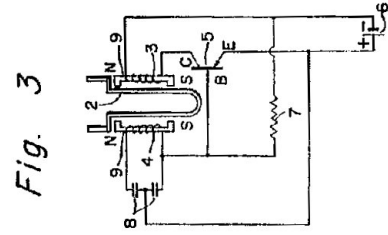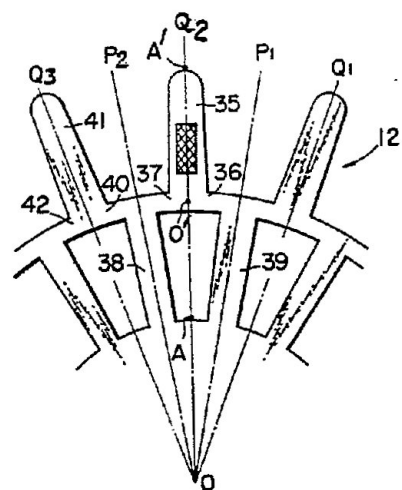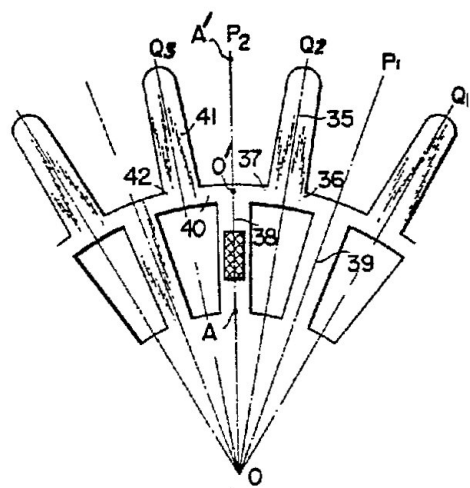
Fig. 6

Fig. 7

Fig. 4

Fig. 5
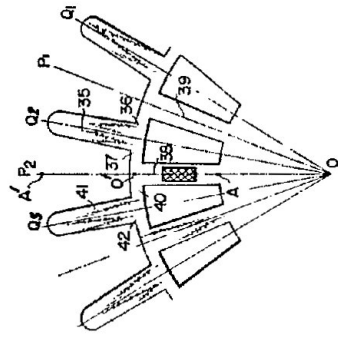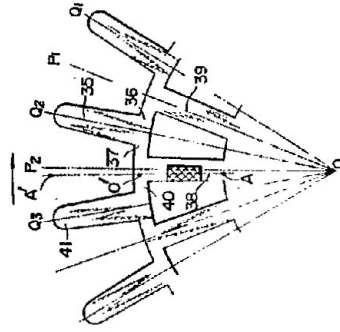
Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

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Fig. 10

Fig. 11

Fig. 12

Fig. 8

Fig. 9