Oct. 5, 1971 F. W. EMERSON ET AL 3,609,957

DRIVE ARRANGEMENT FOR TIMEKEEPING SYSTEM

Filed March 27, 1969

FIG. 1

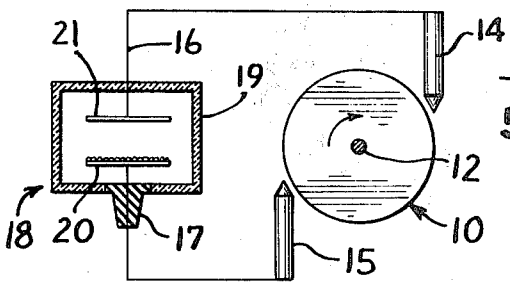


FIG. 4

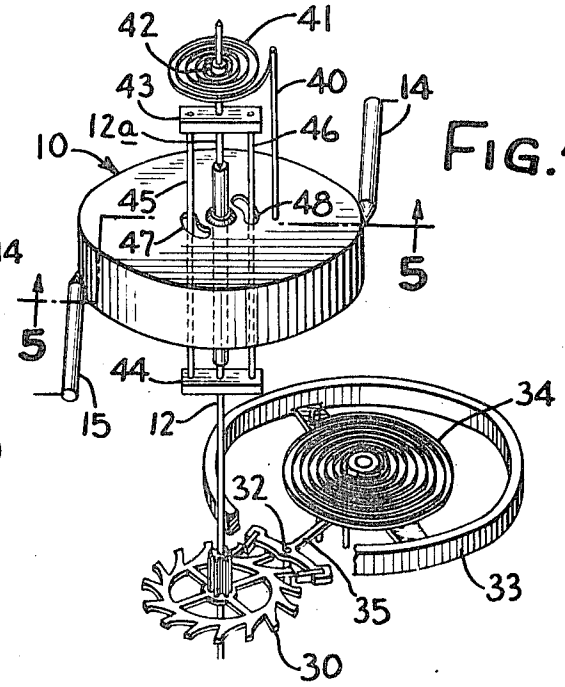
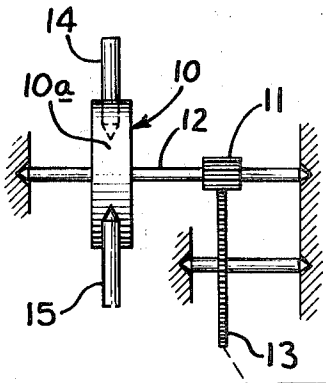


FIG. 2



TIMEKEEPING AND INDICATING MECHANISM

FIG. 5

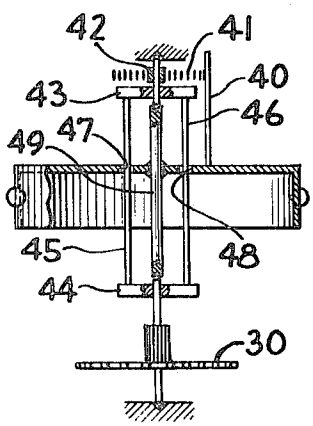
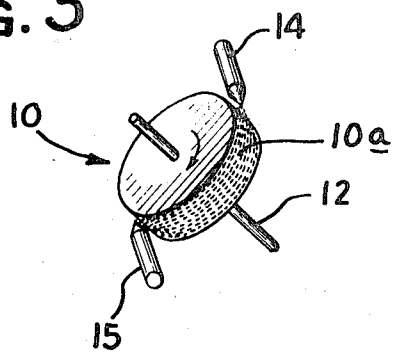


FIG. 3



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United States Patent Office 3,609,957 Patented Oct. 5, 1971

3,609,957

DRIVE ARRANGEMENT FOR TIMEKEEPING SYSTEM

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Filed Mar. 27, 1969, Ser. No. 811,115
Int. Cl. G04c 3/00
U.S. Cl. 58—23 8 Claims

ABSTRACT OF THE DISCLOSURE

An improved drive arrangement for a timekeeping system. The drive arrangement includes an electrostatic motor including a rotor having a dielectric circumferential surface and a pair of electrodes operatively associated with the rotor for driving the rotor in response to D-C potential applied across said electrodes. A nuclear battery is connected to said electrodes for applying a D-C potential across said electrodes to drive said rotor. The torque generated by the rotor is utilized to drive a conventional mechanical time indicating means.

The present invention relates generally to timekeeping systems and, more particularly, to an improved drive arrangement for timekeeping systems.

It is a primary object of the present invention to provide an improved drive arrangement for a timekeeping system which can be operated for a number of years with a single self-contained power source.

It is another object of the invention to provide an improved drive arrangement of the type described above which can be made with only a single moving part.

A further object of the invention is to provide an improved drive arrangement of the foregoing type which produces an output suitable for application to conventional mechanical timing trains for driving conventional indicating elements.

Yet another object of the invention is to provide such an improved drive arrangement which can be powered by a high voltage, low current power source.

A still further object of the invention is to provide such an improved drive arrangement which can be efficiently manufactured at a low cost.

Other objects and advantages of the invention will be apparent from the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic side elevation of a drive arrangement embodying the invention, with the power source shown in section;

FIG. 2 is a schematic end elevation of the drive arrangement shown in FIG. 1;

FIG. 3 is a schematic perspective of the electrode-rotor subassembly in the drive arrangement of FIGS. 1 and 2, and illustrating the electric field between the two electrodes;

FIG. 4 is a perspective view of a drive arrangement embodying the invention; and

FIG. 5 is a vertical section taken along line 5—5 in FIG. 4.

While the invention is susceptible of various modifications and alternative forms, certain specific embodiments thereof have been shown by way of example in the drawings which will be described in detail herein. It should be understood, however, that it is not intended to limit the invention to the particular forms disclosed but, on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

Turning now to the drawings, there is shown a rotor **10** fixed to a shaft **12** which also carries a pinion **11** to be

rotated in response to rotation of the rotor **10**. As the pinion **11** is rotated, it drives a gear **13** connected to a conventional timekeeping and indicating mechanism. That is, the pinion **11** and the gear **13** serve to apply the torque generated by the rotor **10** to a conventional timekeeping and indicating mechanism.

In accordance with the present invention, at least the surface of the rotor **10** is made of a dielectric material operatively associated with a pair of circumferentially spaced electrodes, and a beta primary battery is connected to the electrodes for applying a D-C potential across the electrodes to drive the rotor. Thus, in the illustrative embodiment shown in the drawings, the rotor **10** is molded from a dielectric material, i.e., a material which will support an electric charge without conducting current. A pair of tapered electrodes **14** and **15** are mounted close to the outer circumferential surface **10***a* of the dielectric rotor **10**, and are connected to the positive and negative terminals **17** and **16**, respectively, of a source **18** of relatively high D-C voltage. When this voltage is applied across the two electrodes, ionized gas is produced and the dielectric rotor **10** rotates in the direction indicated by the arrows in FIGS. 1 and 3.

While it is not intended to limit the present invention to any particular theory, it is believed that the relatively high voltage applied to the electrodes **14** and **15** causes gas atoms in the vicinity of the electrodes **14** and **15** to be ionized thereby producing gas ions in the space adjacent the electrodes **14** and **15**. These ionized "clouds" cause three effects: First, since the adjacent surface **10***a* of the rotor **10** is a dielectric, a charge is collected and retained on the rotor surface **10***a*; because the complementary electrode is of the opposite polarity, there is an attractive force between the rotor charges and the said complementary electrode, which causes rotation of the dielectric rotor **10**. Secondly, the velocity of the ionized cloud caused by the point discharge of electrodes **14** and **15** produces an effect known as "ion wind;" this wind impinging on the rotor surface **10***a* causes torque to be transmitted to the rotor shaft **12**. The third effect of the ionized clouds is to polarize the dielectric material. The dielectric dipole moments may also contribute to the developed rotor torque.

Regardless of whether the particular theory advanced above is a precisely accurate explanation of the observed phenomenon, it has been repeatedly demonstrated that the dielectric rotor **10** does, in fact, rotate in the direction indicated when a relatively high D-C potential (on the order of 6,000 volts, for example) is applied across a pair of electrodes located close to the rotor surface and circumferentially spaced therealong. Moreover, it has been found that such a system is capable of generating a torque sufficient to drive a conventional mechanical timekeeping and indicating system when the electrodes are connected to currently available D-C voltage sources. Specific working examples of such a drive system will be described in more detail below. It should be noted that the magnitude of output torque generated by any particular system embodying this invention is dependent upon a number of interdependent variables, such as the size of the rotor, the electrode spacing both with respect to each other and the dielectric rotor surface, the magnitude of the potential applied across the electrodes, the particular ionizable gas surrounding the electrodes and the dielectric rotor surface, the electrode material, the electrode shape, the dielectric material, the pressure of the ionizable gas, the temperature of the electrodes and the surrounding gas, and the like.

In accordance with one particular aspect of the invention, the electrodes are mounted so that the axes thereof are substantially tangential to the dielectric surface of the rotor. Thus, in the illustrative embodiment, the electrodes **14** and **15** are mounted so that the projected axes of the

two electrodes are tangent to the circumferential dielectric surface of the rotor **10** on diametrically opposite sides thereof. It has been found that this particular orientation of the electrodes relative to the rotor provides reliable rotor movement in a preselected direction, e.g., in the direction indicated by the arrows in FIGS. 1 and 3 in the illustrative arrangement.

In keeping with the invention, the source of the D-C potential applied across the electrodes **14** and **15** is a beta primary battery. Thus, in the particular embodiment illustrated in the drawings, the source **18** comprises a casing **19** forming a vacuum chamber containing an internal emitter **20** and an internal collector **21**. The surface of the emitter **20** facing the collector **21** is coated with a radioactive material so as to generate a D-C potential across the two external terminals **16** and **17** connected to the collector **21** and the emitter **20**, respectively. Beta primary batteries of the type illustrated are well known per se, and thus the illustrative source **18** will not be described in detail herein. Briefly summarized, the radioactive material on the emitter **20** emits radiation such as beta particles which are collected on the collector **21**, leaving the emitter plate with a positive charge relative to the collector **21**. Since the beta particles expend kinetic energy against the electrostatic field which exists between the cathode and anode, potential energy on the order of several thousand volts is developed at the external terminals. Although beta primary batteries of this type have been known per se, the relatively low power available from such sources has tended to limit the practical application thereof. One of the significant advantages of the present invention is that the electrostatic motor utilizes the high voltage, low current output from the nuclear battery to provide an output torque suitable for driving a conventional mechanical timekeeping and indicating mechanism.

In accordance with a further aspect of the present invention, an escapement mechanism is operatively connected to the rotor via spring means which store energy generated by continuous rotation of the rotor and intermittently drive the escapement mechanism. Thus, in the particular embodiment illustrated in FIGS. 4 and 5, the rotor shaft **12** is connected to an escape wheel **30** associated with a pallet **31** mounted for oscillatory movement about a pallet staff **32**. As will be apparent to those familiar with this art, the escapement mechanism is conventional per se, and includes a balance wheel **33** and a balance spring **34** operatively connected to the pallets **31** via a lever **35**. The spring mass system formed by the balance wheel **33** and the balance spring **34** tends to oscillate at a constant frequency in response to driving impulses applied thereto by the escape wheel **30** as it is driven by the shaft **12**. As successive driving impulses are applied to the spring-mass system via the pallets **31**, the pallets **31** are oscillated about the pallet staff **32** so as to permit only intermittent rotation of the escape wheel **30**, thereby synchronizing the speed of rotation of the escape wheel **30** with the oscillatory frequency of the spring-mass system formed by the balance **33** and the balance spring **34**.

To couple the intermittently rotating escape wheel **30** to the continuously rotating rotor **10** rigidly mounted on shaft **49**, the rotor **10** is connected via post **40** to one end of a spring **41** having its other end secured to the shaft **12***a*. Thus, the energy generated by continuous rotation of the rotor **10** is stored in the spring **41**, and intermittently applied via the shaft **12** to the escape wheel **30** during the successive intervals when the escape wheel is released by the oscillating pallets **31**.

To permit the spring **41** and the escape wheel **30** to be mounted on opposite sides of the rotor **10** a coupling means interconnects the spring **41** and the escape wheel **30** through the rotor, and the coupling means and the rotor are designed to permit rotational movement of rotor relative to the coupling means. Thus, in the illustrative embodiment of FIGS. 4 and 5, the inner end of the spring **41** is fastened to the shaft **12***a* by means of a collet **42**. Also secured to the shafts **12** and **12***a* on opposite sides of the rotor **10**, are a pair of cross arms **43** and **44** which link a pair of spaced rods **45** and **46** extending through the rotor **10**. Since the shaft **12** rotates only intermittently, during the intervals when the escape wheel is released by the pallet **31**, the rods **45** and **46** also rotate only intermittently. Accordingly, to permit continuous rotation of the rotor **10**, the rods **45** and **46** are passed through a pair of arcuate slots **47** and **48** formed in the central portion of the rotor. Thus, during the intervals when the escape wheel **30** is stationary, the rotor **10** continues to rotate so that the trailing edges of the slots **47** and **48** approach the rods **45** and **46**, respectively. Then when the escape wheel **30** is released to rotate the shafts **12** and **12***a* and the rods **45** and **46**, the rods advance toward the leading edges of the slots **47** and **48**. Consequently, it can be seen that the intermittent movement of the shaft **12** and the rods **45** and **46** does not interfere with the continuous rotation of the rotor **10**.

In one working example of the arrangement shown in FIGS. 4 and 5, a rotor ¾" in diameter, and having an axially extending peripheral flange ¼" in length, was made of polyvinylacetal (("Delrin")), which is dielectric material. The rotor weighed 250 milligrams. This rotor was secured to the escape wheel of a conventional mechanical clock movement of the type used in the commercially available "Ships Bell" clock made by Seth Thomas, division of General Time Corporation. A pair of electrodes were made by forming 0.2-inch long cones on the ends of two cylindrical rods ⅛-inch in diameter and made of high carbon steel. These electrodes were mounted on diametrically opposite sides of the rotor, with the axes of the conical electrodes extending tangentially to the outer periphery of the disc, and with the tips of the electrodes spaced 1/64-inch from the circumferential surface of the dielectric rotor. With the entire assembly disposed in ambient air at room temperature, the output terminals of a constant current nuclear battery producing 5,000 volts D-C were connected to the two electrodes. The rotor rotated at a speed of 8 r.p.m., while driving the clock movement to which it was connected. The current flow in the electrode circuit was measured and found to be one nano ampere (1×10^{-9}), which meant that the calculated power supplied by the drive arrangement was 5 microwatts

(power=voltage×current=$5000\times1\times10^{-9}=5\times10^{-6}$ watts=5 microwatts).

We claim as our invention:

1. An improved drive arrangement for a timekeeping system comprising the combination of an electrostatic motor including a rotor mounted for continuous rotation and having a dielectric circumferential surface and a pair of electrodes operatively associated with said dielectric surface of said rotor for driving said rotor in response to a D-C potential applied across said electrodes, said electrodes being angularly spaced apart around the dielectric circumferential surface of said rotor, a nuclear battery connected to said electrodes for applying a D-C potential across said electrodes to drive said rotor, and output means connected to rotor for applying the torque generated by said rotor to mechanical time indicating means.

2. An improved drive arrangement for a timekeeping system as set forth in claim **1** wherein said electrodes are elongated along axes which extend substantially tangential to the dielectric surface of said rotor.

3. An improved drive arrangement as set forth in claim **1** wherein said electrodes are mounted on diametrically opposite sides of said rotor in closely spaced relationship to said dielectric surface.

4. An improved drive arrangement as set forth in claim **1** wherein said electrodes are mounted in closely spaced relationship to said dielectric surface on said rotor.

5. An improved drive arrangement as set forth in claim **1** wherein said nuclear battery comprises means forming

a vacuum chamber, and first and second internal electrodes spaced apart from each other within said vacuum chamber, one of said electrodes having a surface of radioactive material to generate a D-C potential, the other of said electrodes being provided for charge collection.

6. An improved drive arrangement as set forth in claim 1 wherein said nuclear battery is a beta primary battery.

7. An improved drive arrangement as set forth in claim 1 which includes an escapement mechanism operatively connected to said output means, and said output means includes spring means operatively connected to said rotor and said escapement mechanism for storing energy generated by continuous rotation of said rotor and intermittently driving said escapement mechanism.

8. An improved drive arrangement as set forth in claim 7 wherein said spring means is mounted on one side of said rotor and said escapement mechanism is mounted

on the other side of said rotor, and coupling means interconnected said spring means and said escapement mechanism through said rotor, said coupling means and said rotor being designed to permit rotational movement of said rotor relative to coupling means.

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U.S. Cl. X.R.

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