Oct. 18, 1966 F. W. PFLEGER 3,279,653

ESCAPEMENT CONTROLLED DISPENSING APPARATUS

Filed Dec. 17, 1964

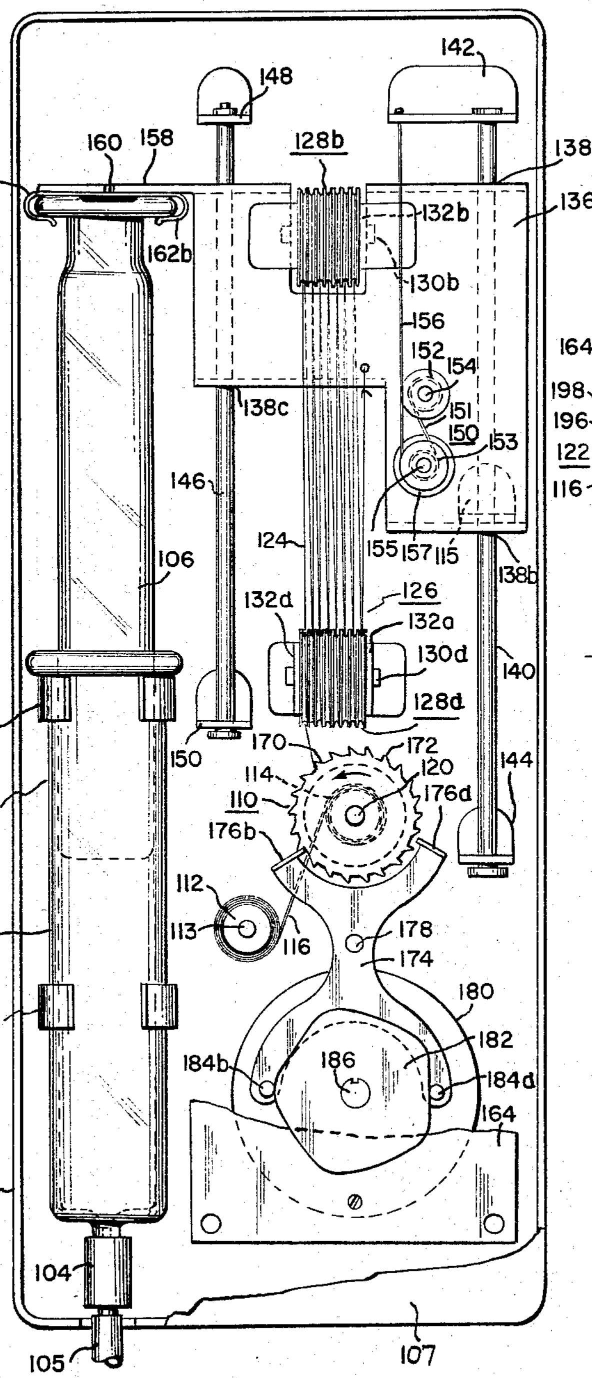

Fig. 1.

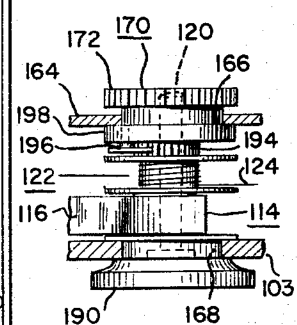

Fig. 2.

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United States Patent Office 3,279,653
Patented Oct. 18, 1966

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3,279,653
ESCAPEMENT CONTROLLED DISPENSING APPARATUS

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Filed Dec. 17, 1964, Ser. No. 418,997
12 Claims. (Cl. 222—70)

This invention relates to dispensing apparatus and, in particular, to a portable dispensing mechanism that has an extremely low dispensing rate, such as is desired for the injection of certain medicines or chemicals into humans, animals or plants.

Many newly available drugs must be administered at extremely low dosage rates over long periods of time. For example, certain new drugs used in the treatment of human cancer are administered at the rate of 20 cc. over 100 hour period. Conventional dispensers for administering medicines at this rate require motor power and are not portable, with the result that the patent generally must be confined to bed throughout the period of treatment. Moreover, therapy of this type is normally administered in a hospital or clinic, with the result that the treatment is very costly. These results could be avoided by the use of a portable dispensing apparatus.

It has been suggested that a portable dispenser might be battery powered, gas pressure powered, or mechanically powered, and that the medicines or chemicals could be dispensed from plastic containers or special bags. Each of these suggested systems has certain disadvantages. One disadvantage of a system using a battery powered motor is the requirement of replacing or recharging the batteries often due to the energy requirement of the system, resulting in unattended operation for a short period only. A disavantage of gas pressured actuators is the requirement of the availability of the gas charges and the high cost of nozzles and regulators. Extremely fine and precision nozzles are required for a low dispensing rate. A disadvantage of the special bag or plastic container is the required availability of special filling equipment and/or a large inventory of filled bags to handle the various proportions and mixtures that are required.

Accordingly, it is one object of this invention to provide a portable dispensing mechanism which enables the dispensing of material, such as medicines and/or chemicals, at an extremely low rate for a long period of time.

It is another object of this invention to provide a portable dispensing device in which no special power source, tools or replaceable components are required.

It is still another object of this invention to provide a portable dispensing apparatus which is adaptable to the use of a standard medicinal syringe if the ingredients are variable, or to the use of a disposable, pre-filled syringe for the fixed formula.

It is yet another object of this invention to provide a portable dispensing device in which the dispensing action is of the positive displacement type, so that the rate of administration of the drug is known and fixed.

A further object of this invention is to provide a portable dispensing mechanism which has a very high efficiency so that its size and weight can be kept to a minimum.

In the injection of medicines into the blood system at an extremely low rate, the blood has a tendency to coagulate aroud the orifice of the injecting element. More pressure is then required from the dispenser than would be required in the absence of coagulation. It has been found that this requirement can be avoided by dispensing the medicines in short pulses such that the average rate of flow is maintained.

Accordingly, it is still another object of this invention to provide a portable dispensing apparatus which is operative to dispense material in pulses.

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Briefly stated, the invention includes a source of mechanical power operatively coupled to the moveable element of a dispenser, preferably by way of a force multiplier device. The power output of the source is released intermittently under control of a timing mechanism, which may exercise control through an escapement mechanism.

In the accompanying drawing:

FIGURE 1 is a plan view of a portable dispensing apparatus, with cover removed, embodying the invention; and,

FIGURE 2 is a view of the spring motor output spool, drive and control assembly in right side elevation, with the bearing plates being shown in section.

In dispensing systems, one of the first items to be considered is the chamber or container for holding the material to be dispensed. In fluid dispensers in the medical and/or laboratory field, one of the most perfected and conventional containers is the hypodermic syringe, hereinafter referred to as a "syringe." Syringes are readily available in a variety of sizes, are easily sterilized, and are also readily available as disposable units. Professional personnel are very adept at filling syringes and varying the mixtures. Such a syringe **100** is shown in FIGURE 1 mounted in a pair of substantially U shaped spring clips **102**^{a}, **102**^{b}, each of which is secured to the dispenser housing **103**. Only the lower or mechanism portion of the housing is illustrated in the drawing. A cover or upper housing portion **107**, only partially shown, of conventional type can be utilized. The syringe **100** has a barrel **101** or chamber and a plunger **106** which fits into the barrel. Barrel **101** is terminated at its lower end in a fitting **104** to which a flexable tubing **105** may be coupled for transporting the dispensed fluid to any desired portion of the body.

In the preferred embodiment illustrated, the movable plunger **106** is the positive displacement element. Alternatively, plunger **106** could be held stationary and the barrel **101** or chamber could be moved to achieve the positive displacement action. When plunger **106** is moved relative to barrel **101**, the only energy not used in the actual dispensing operation is the energy required to overcome the friction between plunger **106** and the inner wall of the barrel **101**. In other systems, such as in a roller dispenser or finger action dispenser in which rollers or levers successively compress tubing, energy is required to deform the tubing as well as to overcome friction.

A spring motor, indicated generally by the reference numeral **110**, includes a take-up spool **112** and a power output spool **114**. Take-up spool **112** is rotatably mounted on a cantilever stud **113** secured to the lower housing **103**. A ribbon spring **116**, in the form of a long length of spring material, is wound around the two spools **112**, **114** and the opposite ends of the spring **116** are secured to the respective spools. The length of the spring **116** required is determined by the stroke of the plunger **106** and the ratio of the force required by the plunger relative to the output power of the spring motor **110**. This will become clearer as the discussion proceeds. In the preferred arrangement, the spring **116** is a constant force spring of the so-called "negator" type which will provide uniform force to operate the plunger **106** over its full stroke. However, any other suitable type spring could be used.

Power output spool **114** is mounted on a shaft **120**. Also mounted on shaft **120** and constrained to rotate with spool **114** is a pulley drum **122** (FIG. 2). Wrapped around drum **122** and fastened at one end thereto is a length of flexible material illustrated as a cord **124**. The output of the spring motor **110** produces a tension force in this cord. Cord **124** is wound around a plurality of pulleys in a multi-pulley system **126** (FIGURE 1) to obtain a desired or necessary step-up of force for operating the plunger **106**. One half of the pulley system **126** comprises a first, stationary set of pulleys **128*a*** mounted on a common shaft **130*a*** carried in bearing supports **132*a*** secured to the dispenser case or housing **103**. The other half of the pulley system comprises a second set of pulleys **128*b*** mounted on a shaft **130 *b*** which is carried in bearing supports **132*b***, These latter bearing supports **132*b*** are secured to a moveable carriage **136**.

Carriage **136** is provided with a three-point bearing structure **138*a*, 130*b*, 138*c*** so that linear motion only can be imparted to the carriage **136** by the pull of the pulley system **126**. The bearing points **138*a*** and **138*b*** slide on a shaft **140** which is carried by shaft supports **142** and **144** mounted on the case **103**. Shaft **140** is parallel to the syringe **100**. The other bearing point **138*c*** slides on a shaft **146** which is carried by a pair of shaft supports **148** and **150** mounted on the case **103**. Shaft **146** serves as a guide unit which prevents rotation of the carriage **136** about shaft **140**, and maintains the proper alignment between carriage **136** and the plunger **106**.

A second spring motor **150** is carried on the carriage **136** and comprises a constant force spring **151** wound around a take-up spool **152** and a power output spool **153**. Spools **152** and **153** are rotatably mounted on cantilever stunds **154** and **155**, respectively, secured to the carriage **136**. A cord **156** is attached at one end to the upper shaft support **142** and is wound around a drum **157** mounted on stud **155**. Drum **157** and power output spool **153** are constrained to rotate together. When the carriage is pulled in a downward direction by main power cord **124**, drum **157** rotates in a clockwise direction to unwind cord **156** the necessary amount. Power output spool **153** is rotated clockwise with drum **157** and winds up the spring **151** in the process. The take-up spool **152** and the force of the spring **151** operate to maintain tension in the cords **156** and **124**. Also, the energy stored in the spring **151** as it becomes wound around the power output spool **153** is used to return the carriage to its upper or start position when the system is reset, as will be described.

An arm **158** projects from the carriage **136** at the upper left side thereof, as viewed in FIGURE 1. Secured to this arm **158**, on the side thereof facing the plunger **106**, is a pusher bumper **160** and a pair of pull clip fingers **162*a*** and **162*b*** which captivate the free end of the plunger **106**. Consequently, any movement of the carriage **136** will, in turn, impart 1:1 movement to the plunger. The pulley system **126** described hereinabove, produces a step-up in force between the output of the main spring motor **10** and the carriage **136** and plunger **106**. The step-up in force or power is a function of the number of pulleys in each of the pulley sets **128*a*, 128*b***. The distance travelled in a downward direction by the carriage and plunger per counterclockwise increment of rotation of the main power output spool **114** varies inversely with the number of pulleys in each set, and thus varies inversely with the force step-up. Accordingly, as mentioned previously, the length of the spring **116** required is a function of the stroke of plunger **106** and the step-up in force produced by the pulley system **126**.

In order to provide adequate bearings for the main power output spool **114** and the pulley drum **122**, the assembly is sandwiched between the lower housing or case **103** and an upper plate **164**, as best seen in FIGURE 2. A major portion of the upper plate **164** is cut away in FIGURE 1 for clarity of drawing in illustrating the active members as seen in FIGURE 2, an upperbearing **166** and a lower bearing **168** are mounted on the shaft **120**, to be further described, and cooperate with bearing holes in the upper plate **164** and case **103**, respectively, to provide alignment and support for the power output spool **114** and pulley drum **122**. The bearings are constrained to rotate with the latter elements in normal operation.

In the normal operation of a spring motor, the motor

gives up its energy at a rate equal to the rate at which energy is absorbed by the driven mechanism. In the present system, energy from the main spring motor **110** is released intermittently under the control of an escapement mechanism. The escapement mechanism includes an escapement wheel **170** mounted on shaft **120** and constrained to rotate with power output spool **114** and pulley drum **122** in normal operation. Escapement wheel **170** preferably is a sprocket wheel. An escapement detent or arm **174** is pivotally mounted on a pin **178** and has a pair of fingers **176*a*, 176*b*** spaced to alternately engage teeth **172** of the sprocket wheel **170**. The spacing between the engaging surfaces of the fingers **176*a*, 176b** is equal to the sum of the chordal distance of the wheel **170**, at the depth of those two teeth which are adjacent the respective fingers, plus the depth of one tooth, plus nominal clearance. Therefore, it is impossible for the spring motor to free-run, since one finger **176*a* 176*b*** or the other will always be in interfering engagement with a tooth on the sprocket wheel **170**.

Fingers **176*a*** and **176*b*** are so located that a perpendicular line to the radial surface of the engaged tooth, at the point of engagement, passes through the center of rotation (pin **178**) of the escapement arm **174**. Consequently, the back or restraining force on the spring motor **110** is in a direction through the center of pivot pin **178**, whereby it does not produce a couple operative on the escapement arm **174**. Therefore, the only power required to operate the escapement arm **174** is the power to overcome friction at the point of engagement of a finger and sprocket tooth, and friction between the arm **174** and pivot pin **178**.

In order to activate the escapement arm **174** under a fixed program for a long period of time, a clock-type mechanism can be utilized. This mechanism, which can be a timer of conventional type, is represented symbolically in FIGURE 1 as a member **180**. A suitable timer, for example, is an eight day travel clock. In the preferred embodiment, clock **180** is mounted on the underside of upper plate **164**. A timing cam **182** is coupled to the output of the clock. For example, cam **182** may be mounted on the minute hand shaft **186** of the clock.

The timing cam **182** is a multi-lobe cam. The number of lobes determines the pulse rate of the dispenser. Changing the number of lobes changes the frequency at which the escapement is operated and thereby provides a method of varying the system pulse rate. Rotation of the cam **182** by the timing mechanism **180** imparts oscillatory motion to the escapement arm **174** through a pair of cam followers **184*a*, 184*b***, which may be integral parts of the arm **174**. The cam followers and cam are designed so that both of the followers **184*a*, 184*b*** always are in engagement with the cam, resulting in a positive action system. Thus no springs are required to urge the cam followers against the cam. This is a distince advantage insofar as loading on the timing mechanism is concerned; if a spring were employed, the timer would have to supply added power to overcome the bias force provided by the spring. As it is, the only energy required of the timing unit is the energy required for its own operation plus the energy to overcome the previously mentioned friction of the escapement mechanism. With modern materials and construction techniques, this friction may be quite low, with correspondingly small energy required.

Actual dispensing of medicine or other substance from the syringe **100** takes place when the plunger **106** is driven in a downward direction. In order to accomplish this, the power output spool **114** and the pulley drum **122** must rotate in a counterclockwise direction, under action of the main power spring **116**, when the engaged sprocket tooth is released by an engaging finger **176*a*** or **176*b***: The sprocket wheel **170**, when released, also must rotate with the power output spool for proper operation.

On the other hand, in order to reset the carriage **136** initially to a start position, at the top of its travel for example, the power output spool **114** and pulley drum **122** must be rotated in a clockwise direction. However, the sprocket wheel **170** can only be rotated counterclockwise since one of the escapement fingers **176***a*, **176***b*, is in engagement with a sprocket tooth and the escapement arm **174** is under control of the cam **182**. Attempted rotation of the sprocket wheel **170** in the clockwise direction could cause a jamming action and possible stripping of sprocket teeth **172**.

In order to permit clockwise rewind of the power output spool **114** and pulley drum **122** without rotation of the sprocket wheel **170**, the power assembly of FIGURE 2 is divided into two sections. The upper section comprises the sprocket wheel **170** and upper bearing **166**. The lower section comprises pulley drum **122**, power output spool **114** and lower bearing **168**. The upper and lower sections are held together in alignment by center shaft **120**. A knob **190** is located on the outside of the case **103** and is secured to the lower bearing **168**.

Rotational movement of the assembly is controlled by means of a one-way ratchet consisting of a ratchet wheel **194** forming a part of the lower section, and a unidirectional ratchet detent **196** pinned to a member **198** in the upper section (FIGURE 2). Detent **196** is urged by a spring (not shown) into engagement with the ratchet wheel **194**. The teeth of the ratchet wheel **194** and the detent **196** are so arranged that the ratchet wheel may be rotated freely of the detent in a clockwise direction, as viewed in FIGURE 1, but cannot be rotated freely in a counterclockwise direction. Accordingly, in the counterclockwise direction all of the elements **114, 122, 166, 168, 170** and **194** must rotate together. However, the power output spool **114**, pulley drum **122**, ratchet wheel **194**, and bearing **168** may be rotated in the clockwise direction, under control of knob **190**, independently of the sprocket wheel **170**, upper bearing **166** and detent **196**.

In a typical operation of the dispenser, an operator removes the syringe assembly **100** (FIGURE 1) from its holding clips **102***a*, **102***b*, **162***a*, **162***b*, and either refills the syringe or prepares a replacement. The operator then winds the knob **190** (FIGURE 2) in a direction to rotate power output spool **114** and pulley drum **122** in a clockwise direction (FIGURE 1). This action rewinds the main power spring **116** on the power output spool **114** and causes energy to be stored in the spring. Clockwise rotation of the pulley drum **122** causes the associated cord **124** to unwind, whereupon the carriage **136** is driven in an upward direction under control of the spring motor **150** mounted on the carriage. In particular, the energy stored in the spring **151** causes the power output spool **153** to rotate in a counterclockwise direction and causes take-up spool **152** to rotate in the clockwise direction. In the process, cord **156** winds around drum **157** to move the carriage in an upward direction and maintain the tension in main cord **124** as the latter is released from drum **122**.

The knob **190** is turned by the operator an amount sufficient to allow return of the carriage **136** to a desired starting point. The syringe **100**, which now has its plunger **106** withdrawn the correct amount, is placed in the housing with the barrel **101** inserted in the clips **102***a* and **102***b* and with the plunger captivated by the clip fingers **162***a*, **162***b*.

The clock **180** or timer may be rewound at this time. The dispensing operation thereafter is automatic. Timer **180** rotates shaft **186** continuously to rotate cam **182**. Cam **182** oscillates escapement arm **174** back and forth at a rate determined by the speed of shaft **186** and the number of lobes on the cam **182**. As an escapement finger **176***a* or **176***b* is rotated out of engagement with a sprocket tooth **172**, energy stored in the main spring **116** is released to rotate power output spool **114** counterclockwise a distance equal, or approximately equal, to one-half the angular spacing between adjacent sprocket teeth. In turn, the pulley drum **122** is rotated the same angular amount and winds the cord **124** on the drum. The power output of the spring motor **110** is stepped up by the multi-pulley system **126** and drives carriage **136** and plunger **106** in a downward direction.

The pulse rate of the dispenser, that is the number of times the plunger **106** is moved in a downward direction per unit of time, is determined by the speed of the timer shaft **186** and the number of lobes on the cam **182**. The amount of medicine dispensed per pulse is determined by the number and spacing of the teeth **172** on the sprocket wheel **170**, the diameter of pulley drum **122**, and the number of pulleys. Thus, the pulse rate may be changed by changing the cam **182** to one having a different number of lobes. The amount of medicine dispensed per pulse can be changed by changing the sprocket wheel **170**.

What is claimed is:

1. The combination comprising:
a dispenser having a chamber and a plunger, one of which is moveable;
a spring motor having a rotatable output member;
a timing mechanism controlling the rotation of said output member;
a carriage constrained to move parallel to said plunger;
a first set of pulleys mounted in fixed space relation relative to said motor;
a second set of pulleys mounted on said carriage;
a pulley drum constrained to rotate with said output member;
a pulley cord wound around said drum and linking each of said pulleys; and
means on said carriage engaging the moveable member of said dispenser.

2. The combination comprising:
a dispenser having a moveable actuator;
a spring motor including a rotatable take-up spool, a rotatable power output spool, and a length of spring material partially wound around each said spool in a direction to rotate said power output spool in a first angular direction;
a member constrained to rotate in said first angular direction with said power output spool;
a moveable escapement detent engaging said member to prevent rotation thereof;
a rotatable cam controlling the position of said detent;
a timing mechanism for rotating said cam;
a force step-up system coupled to the output of said spring motor; and
means applying the output of said force step-up system to said actuator.

3. The combination comprising:
a dispenser having a moveable actuator;
a spring motor including an output spool, and a drive spring directly coupled to and urging said spool in a first angular direction;
an escapement member coaxial with said output spool and being constrained to rotate with said output spool in said first angular direction;
a moveable escapement detent engaging said escapement member to prevent rotation thereof in said first angular direction;
a rotatable control member positively positioning said detent;
a timing mechanism for rotating said control member; and
a force applying member powered by said spring motor and coupled in driving relation with said actuator.

4. The combination comprising:
a moveable output member;
a spring motor including an output spool and a constant force drive spring directly engaging said output spool and urging said spool in a first angular direction;
an escapement member coaxial with said output spool and being constrained to rotate in said first angular direction with said output spool;
a moveable escapement detent selectively engaging said

escapement member to prevent rotation thereof in said first angular direction;

a rotatable control member positively positioning said detent;

a timing mechanism for rotating said control member; and

a force applying member powered by said spring member and coupled to said output member.

5. The combination comprising:

a dispenser having a moveable actuator element;

a spring motor driving said actuator element and including an output spool, and a constant force spring directly engaging and urging said output spool to rotate;

a rotatable control wheel coaxial with said output spool and driven thereby, said wheel having spaced projections;

a pivotally mounted escapement arm engaging at least one of said projections; and

a timing mechanism for oscillating said escapement arm.

6. The combination comprising:

a dispenser having a moveable element;

a source of constant mechanical force;

a force multiplier coupled between said source and said moveable element;

means controlling the release of said force at said source; and

a timing mechanism having an output member operatively coupled to the control means.

7. The combination comprising:

a dispenser having a moveable actuator element;

a spring motor having a rotatable spool, a constant force drive spring directly urging said spool to rotate, and a rotatable control member coaxial with said spool and driven thereby;

means coupling the output of said motor to said actuator element;

a moveable escapement mechanism operatively coupled to said control member;

a cam positively engaging said escapement mechanism; and

a timer rotating said cam.

8. The combination comprising:

a dispenser having a moveable element;

a spring motor having a rotatable control member thereon;

a moveable escapement mechanism engaging said control member;

a cam positively engaging said escapement mechanism;

a timing mechanism rotating said cam; and

force step-up means operatively coupled between the output of said spring motor and the moveable element of said dispenser.

9. A control mechanism comprising:

a controlled member;

a spring motor having a spring driven spool, and a rotatable control member coaxial with and driven by said spool;

a moveable escapement mechanism operatively coupled to said control member;

an actuating member positively positioning said escapement mechanism;

a timing mechanism connected to said actuating member for controlling said actuating member as a function of time; and

a connection member coupled between said spring motor and said controlled member.

10. The combination comprising:

a spring motor having a rotatable output member;

a timing mechanism controlling the rotation of said output member;

a moveable carriage;

a first set of pulleys mounted in fixed spacial relation relative to said motor;

a second set of pulleys mounted on said carriage;

a pulley drum constrained to rotate with said output member; and

a pulley cord wound around said drum and linking each of said pulleys.

11. Apparatus for the controlled mechanical drive of an output device comprising:

a spring motor including a rotatable take-up spool, a rotatable power output spool, and a length of spring material partially wound around each said spool in a direction to rotate said power output spool in a first angular direction;

a member constrained to rotate in said first angular direction with said power output spool;

a moveable escapement detent engaging said member to prevent the rotation thereof in said first angular direction during engagement by said detent;

a rotatable cam controlling the position of said detent;

a timing mechanism for rotating said cam;

a force step-up system coupled to the output of said spring motor; and

means for applying the output of said force step-up system to the output device.

12. Apparatus for the controlled mechanical drive of an output device comprising:

a spring motor including a rotatable take-up spool, a rotatable power output spool, and a length of spring material partially wound around each said spool in a direction to rotate said power output spool in a first angular direction;

a member constrained to rotate in said first angular direction with said power output spool;

a moveable escapement detent engaging said member to prevent the rotation thereof in said first angular direction during engagement by said detent;

a rotatable cam controlling the position of said detent;

a timing mechanism for rotating said cam; and

means coupling the output of said spring motor to the output device.

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