

Sept. 29, 1959

I. M. SHEAFFER, JR
HIGH SPEED STEPPING APPARATUS

2,906,130

Filed July 29, 1955

2 Sheets-Sheet 1

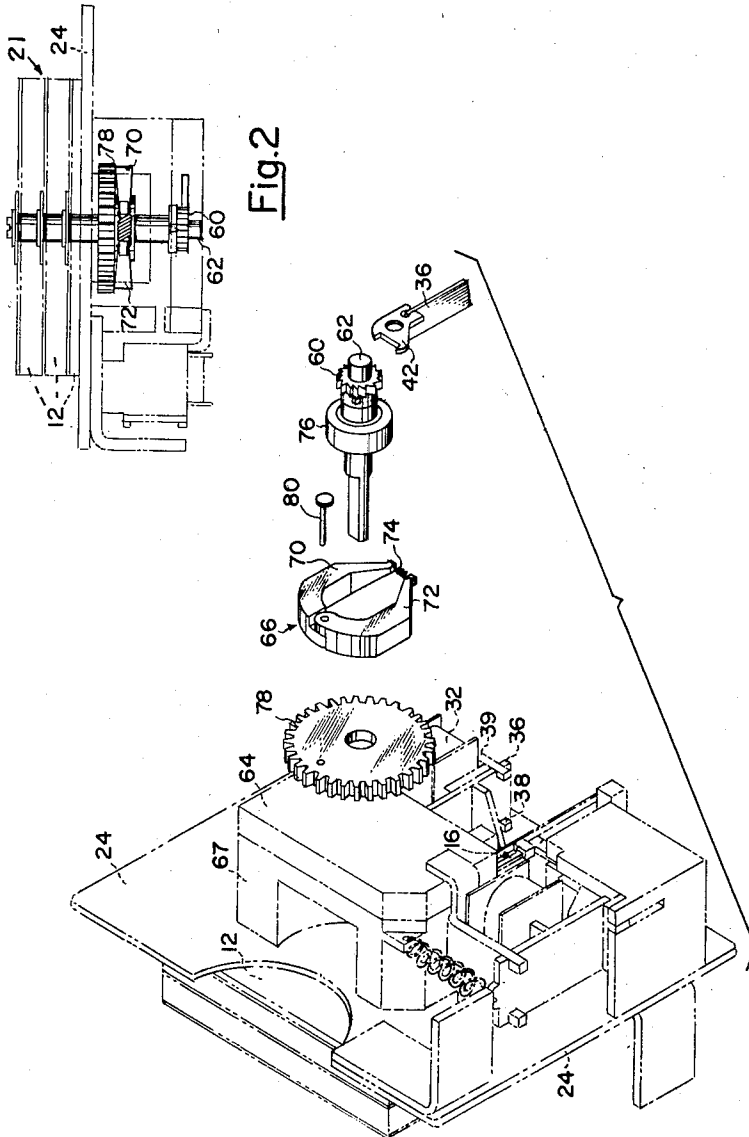


Fig. 1

Fig. 2

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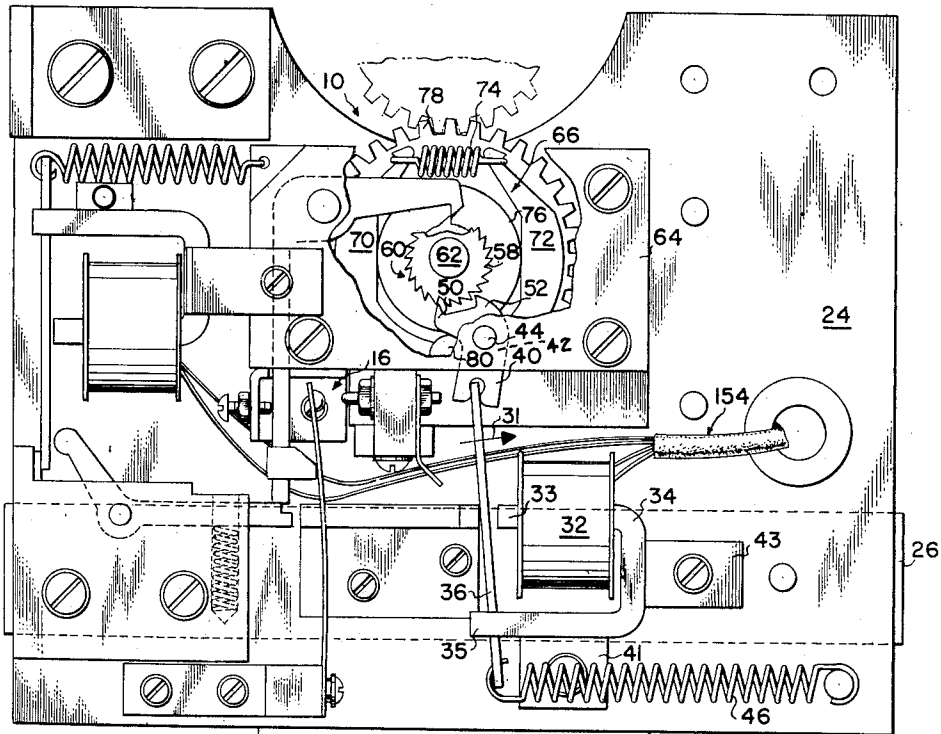


Fig.4a

Fig.4b

Fig.3

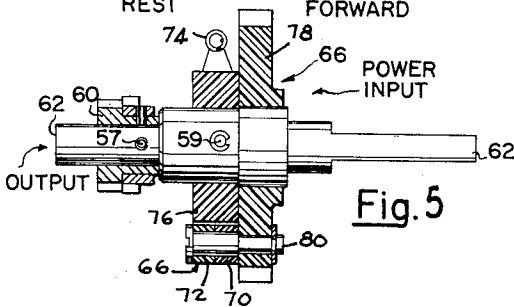
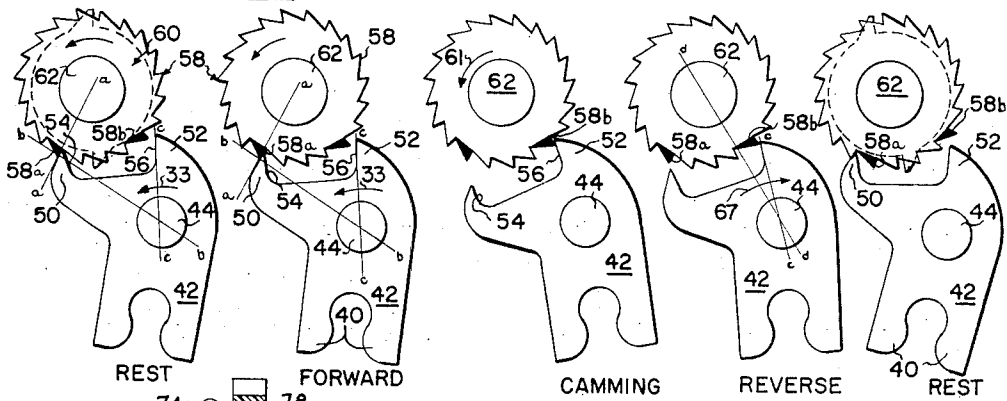


Fig.5

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HIGH SPEED STEPPING APPARATUS

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Application July 29, 1955, Serial No. 525,098

6 Claims. (Cl. 74—84)

This invention relates to stepping mechanisms and more particularly to electrically controlled mechanisms which are operable in step-by-step sequence in response to successive electrical actuating impulses.

Step type switch or counter mechanisms are well known. The conventional driving arrangements for such mechanisms may comprise any one of many well known types. One of these is the type in which the step contacts of the switch are moved under spring tension with the spring itself being energized by a motor drive. Another one of these is the type in which the step contacts are actuated by a direct motor drive.

An important limitation in both of the above-mentioned devices is that as the mass of the switch gear increases so must the driving force that is utilized to move this mass. The use of a high-speed direct motor drive for step type switches while avoiding the limitation due to increased mass has in the past required the use of a starting, stopping and positioning system for the motor which system is expensive and frequently a source of trouble.

The utilization of a spring driven switch contact is equally disadvantageous for the reason that most available spring driven switches of the step type rely on a solenoid and clapper arrangement to drive some type of ratchet or escapement mechanism which is used to provide the required step-by-step actuation. In many of these latter switches detenting of the ratchet wheel by means of the escapement arm or a pawl in order to prevent the ratchet wheel from reversing its direction introduces an undesirable drag into the mechanism tending to urge the ratchet wheel in the opposite direction as the pawl is reset. This drag, which is often appreciable, prevents the realization of the high operating speed which is most desired.

An escapement mechanism utilizing a solenoid armature in conjunction with a constantly driven ratchet wheel and an escapement arm appears to provide the optimum in operating speeds for the last described class of switch gear. However, the conventional solenoid actuated spring drive escapement switch mechanism suffers generally from what is known as a negative camming action, i.e., a turning force in opposition to the return of the escapement arm by the armature return spring. In order to improve the release time of the solenoid, and thereby increase the operating speed of this type of switch, the armature or clapper spring tension must necessarily be increased. This increased tension results in a longer operating or release time for the solenoid which in turn lowers rather than raises the operating speed of the device.

An important object, therefore, of the present invention is to provide an improved step-by-step mechanism having an extremely high operating speed.

It is also an object of the invention to provide an improved stepping mechanism which avoids the drag nor-

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mally imposed by the resetting of the control mechanism.

It is a still further object of the invention to provide a stepping mechanism in which a novel escapement mechanism produces a positive camming action which

resets the control mechanism.

Another important object of the invention is to provide a novel control mechanism of the electromagnetic type which has a relatively faster release time than heretofore.

In accordance with the above objects the present invention provides a novel step-by-step mechanism comprising a rotatable shaft releasably engaging a source of constant torque, and having a toothed ratchet wheel rotatable with the shaft and adapted to operably engage an escapement mechanism including an escapement arm.

One end of the escapement arm is provided with two oppositely disposed individual angular projections or camming surfaces which engage the teeth of the ratchet wheel. The opposite end of the escapement arm is formed so as to receive the armature or clapper of a signal responsive solenoid or similar electromagnetic control device. Driving torque is continuously applied to the shaft but the escapement mechanism holds the shaft stationary until a suitable energizing potential is applied, whereby the escapement arm releases the ratchet wheel and thus the shaft may be rotated. On the first half cycle of movement of the escapement arm, the central shaft is rotated approximately half a tooth on the ratchet wheel. On the second half of the cycle a tooth of the ratchet wheel cams against the angular projections on one side of the escapement arm so as to rock or cam a half tooth distance in the direction of rotation of the ratchet wheel, thus completing the step or cycle.

The features of the invention which are believed to be novel are set forth with particularity in the following specification and in the appended claims. The invention itself, however, both as to its organization and operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawing in which:

Fig. 1 is an exploded view of a mechanism in accordance with the invention as applied to a stepping switch, with parts of the switch in phantom;

Fig. 2 is a top plan view, partially broken away, of the mechanism of Fig. 1;

Fig. 3 is a side elevational view of the mechanism with parts broken away;

Figs. 4a through 4e are enlarged fragmentary views of the novel escapement mechanism illustrating the sequence of operation of the escapement arm and ratchet wheel from the full rest position at 4a, progressively through a forward, camming, reverse to a full rest position at 4e; and

Fig. 5 is a transverse sectional view showing the central drive shaft of the invention.

An operative embodiment of the invention is illustrated in the drawings as applied to a stepping switch and includes the stepping mechanism generally indicated at 10.

The switch assembly, generally indicated at 21, may, for example, comprise a rotary member and one or more electrically insulating boards or panels 12 each containing a plurality of conductors arranged in radiating relation to the rotary member and successively contacted thereby upon member. In order to provide greater flexibility of operation and to produce a relatively simple and extremely efficient unitized, packaged assembly, all of these components are suitably secured to a single rigid plate or frame 24.

Instructions in the form of intelligence signals are fed to the switch mechanism in some predetermined order or sequence so that a "stop-start" or "step-by-step" operation can thereby be accomplished. Any suitable bi-

stable device may be used to produce this result. One simple and relatively inexpensive means for performing this operation is to utilize a signal responsive electromagnetic device which can be energized and de-energized at will and which is provided with mechanical linkages for operating the escapement mechanism of the device. A suitable triggering control device for these purposes comprises an electromagnet or solenoid 32 suitably mounted on the frame 24. The other leg 35 of the core extends along the side of the solenoid and its extremity is shaped to form a rocking support for the solenoid armature or clapper 36. One end of the armature is received in the bifurcated end 40 of an escapement arm 42 pivoted intermediate its ends by means of a pin 44. The opposite end of the solenoid armature is connected to a coiled spring 46 which yieldingly biases the armature away from the core leg 33 and normally holds the same away therefrom except when the solenoid is energized.

In order to increase the overall operating speed and efficiency of the device, the drag imposed upon the escapement mechanism by reason of its armature having to be reset after each step is eliminated, and to this end a "positive" camming action, the operation of which will be explained in detail hereinafter, is built into the escapement mechanism. The end of the escapement arm 40 opposite to that engaged by the solenoid armature is provided with two confronting pointed projections, i.e., click or pallets 50 and 52 having individual inwardly facing surfaces 54 and 56 respectively, thereon, Figs. 4a through 4e inclusive. The inwardly facing surfaces of the pallets are arranged to alternately engage the teeth 58 of a ratchet wheel 60.

It is to be noted at this point that each one of the teeth of the ratchet wheel 60 presents a relatively flat leading face to the leading pallet 50 thereby forming a plane indicated by the line *a*—*a* which is substantially perpendicular to a line *b*—*b* drawn through the axis of rotation, i.e., pivot point of the escapement arm 42 as best shown in Fig. 4a. The relation of these two faces, i.e., of the ratchet wheel tooth and the leading pallet, is such that the transmission of torque from the external source to the teeth of the ratchet wheel will exert no turning force on the escapement arm.

Conversely, the escapement arm trailing pallet 52 presents a tooth face which is on a substantially radial line with the pivot 44 so as to transmit full torque from the ratchet wheel to the escapement arm. It is therefore possible to take maximum advantage of the applied torque in a direction to restore the escapement arm as will be described more fully later on.

The ratchet wheel 60 is secured by a pin 57 (Fig. 5) to a central power input or drive shaft 62. In the illustrated embodiment of the invention, as shown in Fig. 2, the shaft 62 extends through and is journaled in frame plate 24, and in a cover member 64 spaced from the plate by means of the box-like enclosure 67.

It is desirable, in this connection, to separate the driving function of the switch from the control function so that a reduction in weight and number of operating elements may result. A relatively simple and readily available power input device to drive the switch is a source of constant torque which is or may be provided by means of the motor drive normally utilized in the conventional business machine, computer or the like with which the present device may be utilized.

This turning force is applied to the shaft 62 so as to permit the device to perform selective operations at will in response to externally applied intelligence signals as will be described subsequently.

In order to couple the source of constant torque to the central shaft 62 a friction drive or coupling 66, Figs. 1, 3 and 5, is mounted on the shaft adjacent to and concentric with the ratchet wheel 60.

The coupling comprises a pair of substantially C-shaped arms 70 and 72 which extend along opposite sides of the shaft 62. One end of each of the two coupling arms are shaped to overlap one another as shown in Fig. 1, and are pivotally journaled to a toothed drive wheel 78, freely rotatable on the shaft, by means of a pin 80. The free ends of the two arms are biased towards each other by means of the spring 74 and are thus induced to frictionally encircle and grip an enlarged hub 76 rigidly fixed to the shaft 62 by pin 59.

The drive wheel 78 is adapted to engage an external source of constant torque, such as an electric motor (not shown). Application of power to the gear wheel 78 acting through the coupling 66 and hub 76 constantly urges the shaft 62 to rotate. The friction drive 66 is preferably fabricated from some lightweight plastic material such as nylon or Teflon so that little or no lubrication is required and the mass of the members is thereby substantially reduced. The hub 76 of the friction drive may also be of plastic material, and may be force fit to a knurled portion on the shaft 62 or secured thereto by means of the pin 59. As illustrated more clearly in Figure 6, the portion of the shaft 62 having a relatively small diameter has one of the rotating members, i.e., the ratchet wheel 60, secured thereto. In this fashion the diameter of this rotating part is kept small which, by minimizing inertia, tends to further increase the operating speed of the device.

The operation of the mechanism is best illustrated in Figures 4a through 4e of the drawings. Assuming that the switch mechanism is de-energized, it can be seen that, starting the cycle for one complete step at Figure 4a, the escapement arm 42 is at rest or "cocked" and the leading edge of the tooth 58a of the ratchet wheel 60 is resting against the trailing edge of the escapement arm projection or pallet 50. Application of a constant torque to the drive gear 78 causes the friction coupling 66 to slip on the hub 76 and to rotate at the desired operating speed. Momentary energization of the solenoid 32 from an external signal source (not shown) causes the armature or clapper 36 to be rocked about its pivotal axis in the direction of the arrow 31, Figure 3. This causes the escapement arm 42 to rotate counter-clockwise about its pivotal axis 44 in the direction of the arrow 33, Figures 4 and 4b. In Figure 4b it is seen that the pallet 50 is about to disengage the tooth 58a of the wheel 60. At the half cycle of operation of the escapement mechanism the tube is completely disengaged and the solenoid is de-energized. At an instant later, as shown in Figure 4c, the camming surface 56 which is the leading edge of pallet 52 is abutting the leading edge of the tooth 58b and, since the ratchet wheel 60 is now free to rotate in the direction of the arrow 61, the tooth 58b cams the leading edge 56 of the pallet 50 in a clockwise direction, as shown by the arrow 67, Figure 4d, to finish the second half of the step. In this manner one cycle of operation is completed and the escapement arm is returned to a rest position as shown in Figure 4e. The tooth 58a has now escaped from the arm 42 and the pallet 50 comes to rest against the leading edge of the tooth immediately behind this tooth. The torque applied through the frictional coupling is thus used to return or reset the escapement arm and the magnet clapper or armature. Additional steps can be obtained by again triggering or pulsing the solenoid 32 so that the constantly applied torque is permitted to step the switch at will.

Continuous stepping operation of the switch can be provided by causing the solenoid 32 to be pulsed or energized in rapid succession. In this manner the escapement mechanism can step the switch in unison therewith.

The relatively long release time of the solenoid magnet, as before mentioned, introduces an appreciable drag factor into the speed operation of the switch. In order to increase or step-up the release time of the clapper the

spring 46 may be utilized to bias the armature clapper 34 away from the solenoid core 36 thus offering an additional mechanical advantage as well as increasing operating speeds.

Any suitable type of control means may be provided, as before mentioned, in order to pulse the magnet or solenoid 32 so that by successive operation of the ratchet wheel 60 the rotor 86 will be stepped to its next position.

From the foregoing it is to be noted that the escapement mechanism of the present stepping switch is provided with a camming action which manifests itself on the second half of each forward step. This action resets the escapement arm and magnet clapper or armature. By reason of the camming action the torque derived from the main power input is available for the resetting operation. The physical configuration of the pallet 52 on the escapement arm 42 is such that friction between the pallet and any of the teeth 58 will transmit no torque in opposition to the return of the escapement arm. It will be further apparent from the operation of the device that the stepping switch is constructed so as to be operable with or without the armature return spring 46 due to the camming action earlier described and the novel construction of the escapement mechanism.

Although a specific type of friction coupling is shown in the drawing illustrating the present invention, it will be apparent to those skilled in the art, that any type of yielding arrangement which is or may be adapted to transmit a continuous turning force to the central shaft 62 could be substituted for the coupling shown herein. Since all the driving force of the external power source is transmitted through the friction coupling, the camming action provided by the pallets of the escapement arm 42 resets and holds the escapement arm on the second half of the solenoid clapper stroke. This action permits operation of the device with negligible tension on the solenoid return spring. Further, since the motion of the ratchet wheel 60 is "in phase" with the motion and direction of the travel of the escapement arm 42, the tension of the return spring will reduce the drag to the operation of the ratchet wheel.

From the foregoing description, it will be apparent that the novel mechanism herein described permits the utilization of an exceedingly small driven mass. And, since the mass is small, the actuating mechanism may thus provide a higher operating speed. The embodiment of the invention illustrated herein is adapted for operation at speeds in excess of two hundred steps per second.

There has thus been described a novel step-by-step mechanism which receives its driving torque from a constantly rotating external source of power. The torque is applied through a yielding frictionally engaged coupling member. The mechanism is controlled by a solenoid operated escapement device so as to permit instantaneous momentary step-by-step advancement of associated switch gear without appreciably affecting the primary driving source.

It is further apparent that the mechanism described herein is essentially an asynchronous device in that it is capable of accepting pulses at any random frequency equal to or less than the maximum stepping rate for which the device was designed.

What is claimed is:

1. A step by step mechanism comprising a rotatable shaft, drive means urging said shaft to rotate, a ratchet wheel on said shaft, an escapement arm movable between first and second terminal positions, a first pallet disposed on said escapement arm and normally engaging a tooth of said ratchet wheel when said escapement arm is in said first terminal position, a second pallet disposed on said escapement arm and normally out of engagement with the teeth of said ratchet wheel when said escapement arm is in said first terminal position, and means to move said escapement arm to said second terminal position whereby said first pallet is disengaged from said ratchet

wheel to permit rotation of the latter by said drive means, said second pallet when said escapement arm is in said second terminal position being in the path of movement of the teeth of said ratchet wheel and movable thereby to return said escapement arm to said first terminal position again engaging the teeth of said ratchet wheel to stop rotation thereof.

2. A step by step mechanism comprising, in combination, a frame, a shaft supported for rotation in said frame, means for applying a constant torque to said shaft, a ratchet wheel secured to said shaft, an escapement arm movable between two extreme positions in one of which it operatively engages the teeth of said ratchet wheel so as normally to restrain the movement of said wheel, the teeth of said ratchet wheel being disposed with respect to each other to make contact with said escapement arm at such an angle to said arm that no torque is transmitted to said arm while the wheel is in its restrained condition, and a solenoid mounted on said frame and having an armature rockably engaging one end of the escapement arm so that upon energization thereof the escapement arm is moved to the other one of the extreme positions thus to transmit full torque to said shaft.

3. A step by step mechanism comprising, a rotatable shaft, drive means urging said shaft to rotate, a ratchet wheel fixed to said shaft, an escapement arm pivotally mounted for rocking engagement with said wheel, leading and trailing pallets oppositely disposed on said escapement arm, means for rocking said arm from one extreme position to another, the leading pallet of said escapement arm normally engaging a tooth of the ratchet wheel when said arm is in one extreme position, and withdrawn from such engagement when said rocking means moves said arm to its other extreme position thereby allowing the ratchet wheel to rotate in the direction urged by said drive means, said trailing pallet upon such movement of the escapement arm being rocked into the path of movement of another of the ratchet wheel teeth, the angular relation between the leading and trailing pallets of the escapement arm and the teeth of the ratchet wheel being such that the tooth of the ratchet wheel thus abutting the trailing pallet acts when said rocking means is deenergized to cam the pallet out of engagement therewith and rock the escapement arm to its said one extreme position whereby the leading pallet engages a succeeding tooth of the ratchet wheel thus stopping further rotation thereof.

4. An accumulator counter of the step by step type and including a multiposition counting switch having wiper contacts for energizing suitable successive digit indicating circuits, said counter comprising, a rotatable shaft, means urging said shaft to rotate, a ratchet wheel fixed to said shaft for rotating said wiper in step by step fashion to successively engage said circuits, an escapement arm pivotally mounted for rocking movement about an axis offset from the axis of rotation of said shaft, leading and trailing projections oppositely disposed on one end of said escapement arm, electromagnetic means for rocking said arm from one extreme position to another, the leading projection of said escapement arm normally engaging a tooth of the ratchet wheel when said rocking means has placed said arm in one of its extreme positions, said rocking means when moved to its other extreme position acting to withdraw the leading projection from said ratchet wheel teeth thereby allowing the ratchet wheel to rotate in the direction urged by said drive means, said trailing projection upon such movement of the escapement arm being rocked into the path of movement of another of the ratchet wheel teeth, the angular relation between the leading and trailing projections of the escapement arm and the teeth of the ratchet wheel being such that the tooth of the ratchet wheel thus abutting the trailing projection acts to cam the latter projection out of engagement therewith and rock the escapement arm in a direction to bring the leading projection into engagement

with a succeeding tooth of the ratchet wheel to stop further rotation thereof thus to effect step by step rotation of said wipers to successive digit indicating circuits for a counting operation.

5. An accumulator counter of the step by step type and including a multiposition counting switch having wiper contacts for energizing suitable successive digit indicating circuits, said counter comprising a rotatable shaft, frictional drive means urging said shaft to rotate, a ratchet wheel fixed to said shaft for rotating said wiper in step by step fashion to successively engage said circuits and being provided with a plurality of angularly disposed spaced apart teeth, an escapement arm pivotally mounted for rocking engagement with said wheel, leading and trailing protuberances oppositely disposed on said escapement arm, means for rocking said arm from one extreme position to another, the leading protuberance of said escapement arm normally engaging a tooth of the ratchet wheel when said arm is in one of its extreme positions, said arm when urged to its opposite extreme position acting to withdraw the leading protuberance from said ratchet wheel tooth thereby allowing the ratchet wheel to rotate in the direction urged by said drive means, said trailing protuberance upon such movement of the escapement arm being rocked into the path of movement of another of the ratchet wheel teeth, the angular relation between the leading and trailing protuberances of the escapement arm and the teeth of the ratchet wheel being such that the tooth of the ratchet wheel thus abutting the trailing protuberance acts to cam the protuberance out of engagement therewith and rock the escapement arm in a direction such that the leading protuberance engages the next succeeding tooth of the ratchet wheel stopping further rotation thereof thus to effect step by step rotation of said wipers to successive digit indicating circuits for a counting operation.

6. An accumulator counter of the step by step type and including a multiposition counting switch having wiper contacts for energizing suitable successive digit indicating circuits comprising a rotatable shaft, frictional drive means urging said shaft to rotate, a ratchet wheel fixed to said shaft for rotating said wiper in step by step fashion to successively engage said circuits, an escapement arm pivotally mounted for rocking movement about an axis offset from but parallel to the axis of rotation of said

shaft, leading and trailing projections oppositely disposed on one end of said escapement arm, means for rocking said arm from one extreme position to another, the leading projection of said escapement arm normally engaging a tooth of the ratchet wheel when said rocking means has placed said arm in one of its extreme positions, each tooth of the ratchet wheel presenting a relatively flat face to the leading projection of the escapement arm thereby forming a plane which is substantially perpendicular to a line drawn through the pivotal axis of the escapement arm, the relation of the face of the ratchet wheel tooth and the leading projection being such that the urge of said drive means to rotate said ratchet wheel exerts no turning force on said escapement arm, said escapement arm when subsequently moved acting to withdraw the leading projection from said ratchet wheel teeth thereby allowing the ratchet wheel to rotate in the direction urged by said drive means, said trailing projection upon such movement of the escapement arm being rocked into the path of movement of another of the ratchet wheel teeth, the angular relation between the leading and trailing projections of the escapement arm and the teeth of the ratchet wheel being such that the tooth of the ratchet wheel thus abutting the trailing projection acts when said arm is moved to cam the projection out of engagement therewith to rock the escapement arm in a direction to bring the leading projection into engagement with the next succeeding tooth of the ratchet wheel stopping further rotation thereof thus to effect step by step rotation of said wipers to successive digit indicating circuits for a counting operation.

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