Sept. 13, 1949. M. L. HAMLIN 2,482,061

MASTER CLOCK

Filed May 24, 1943 5 Sheets-Sheet 1

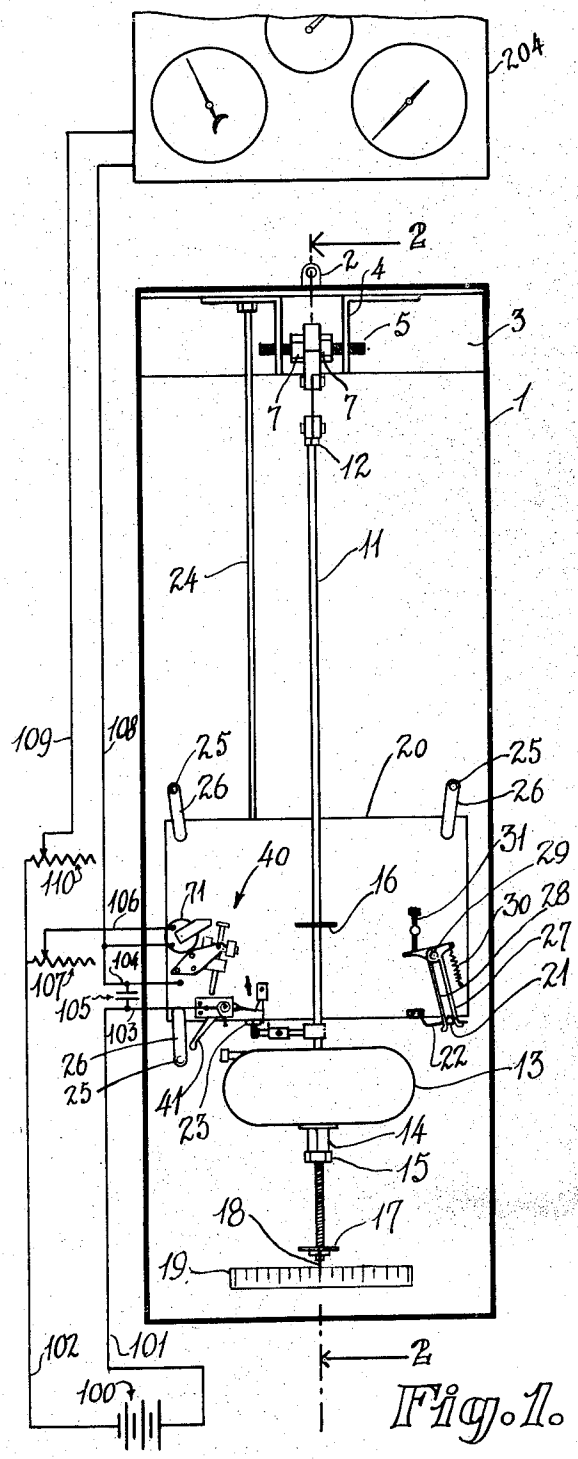
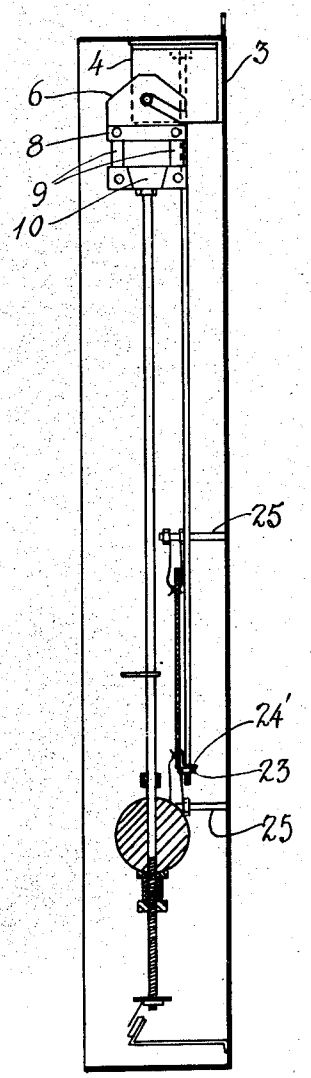


Fig. 1.

Fig. 2.



INVENTOR.

Marston Lovell Hamlin

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Fig. 3.

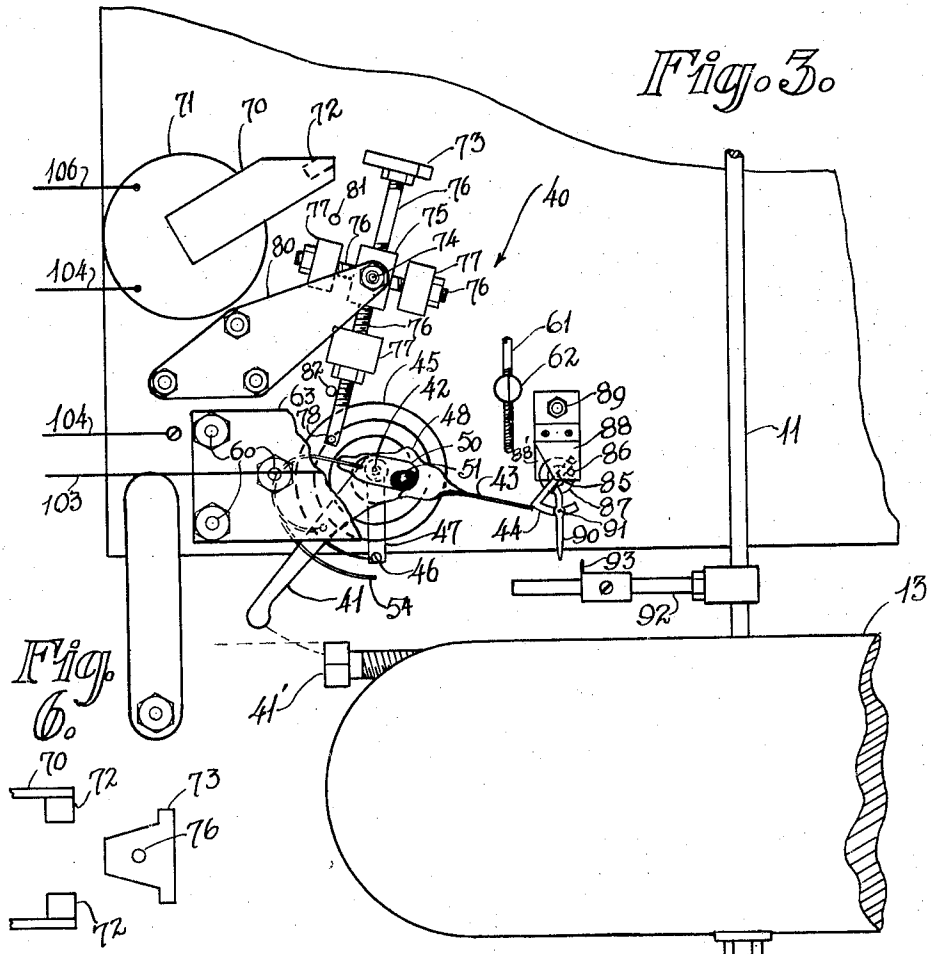


Fig. 6.

Fig. 4.

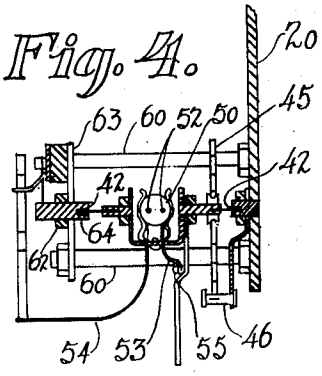
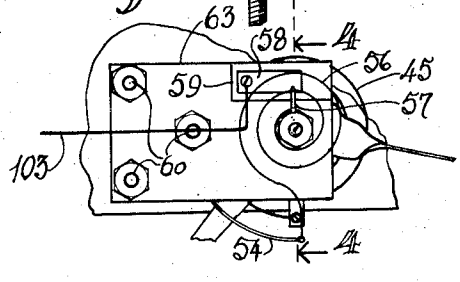


Fig. 5.



INVENTOR.

Marston Lovell Hamlin

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Fig. 7.

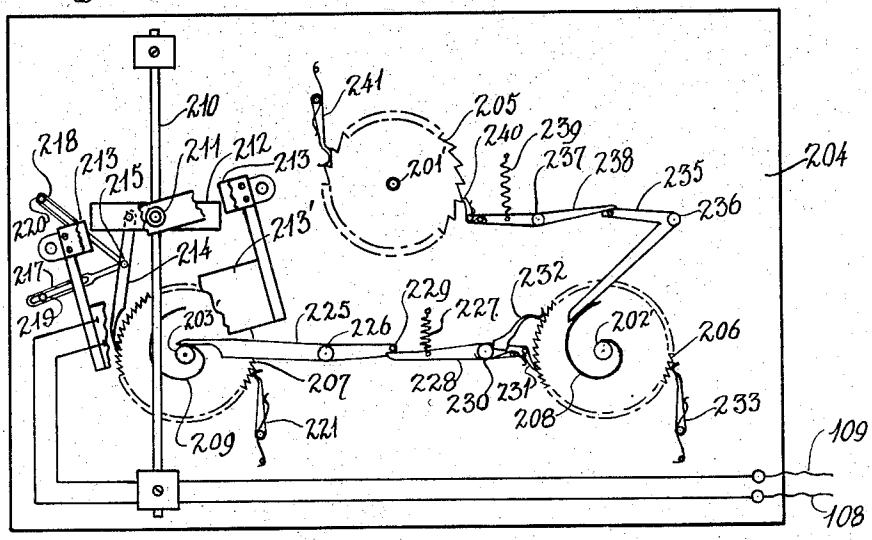
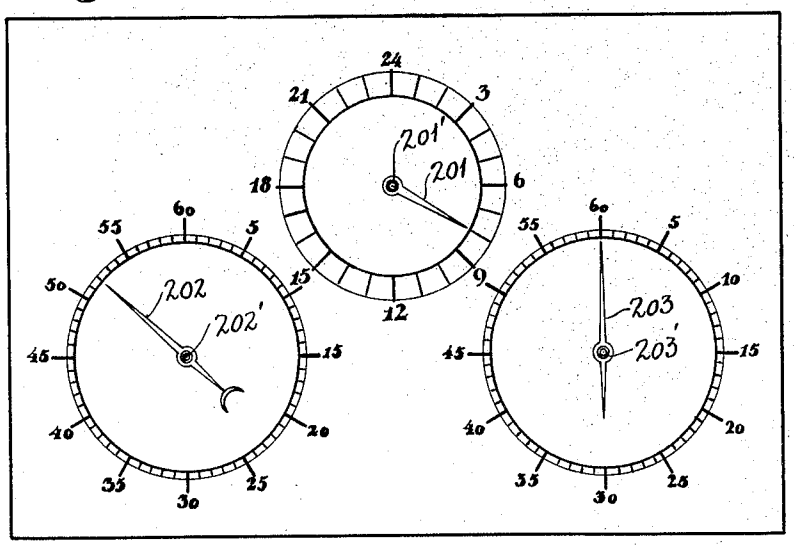


Fig. 8.



INVENTOR.

Marston Lovell Hamlin

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Fig. 9.

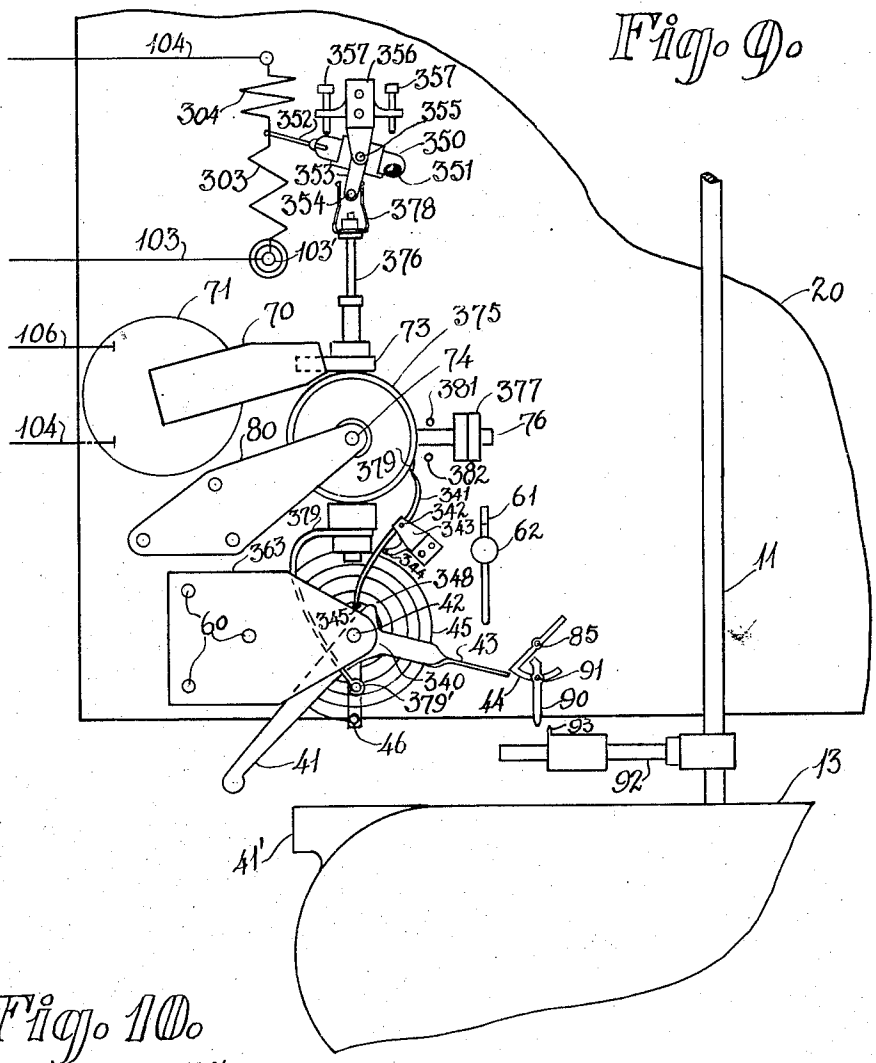
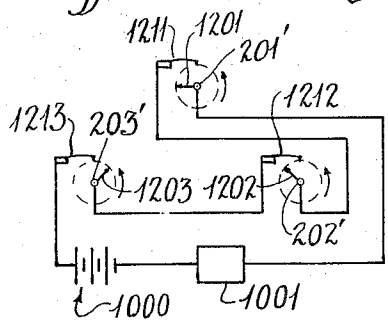


Fig. 10.



INVENTOR.

Marston Lovell Hamlin

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Fig. 11.

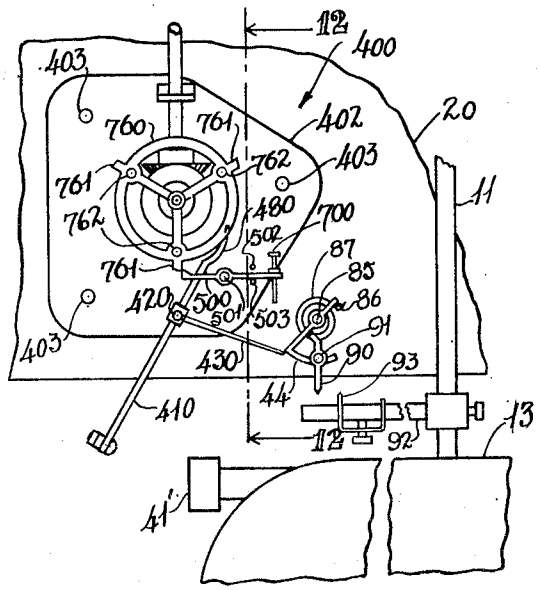


Fig. 12.

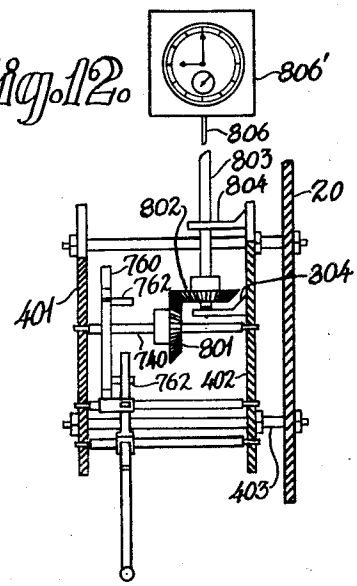


Fig. 13.

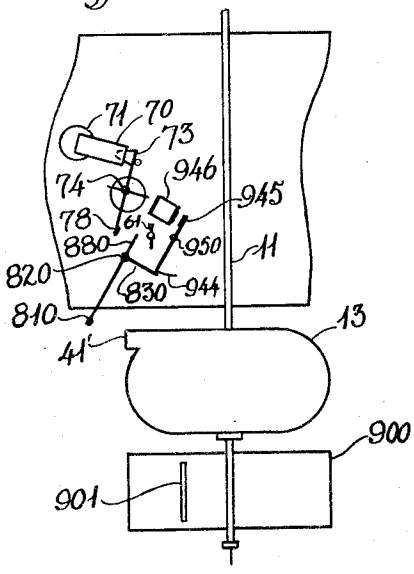
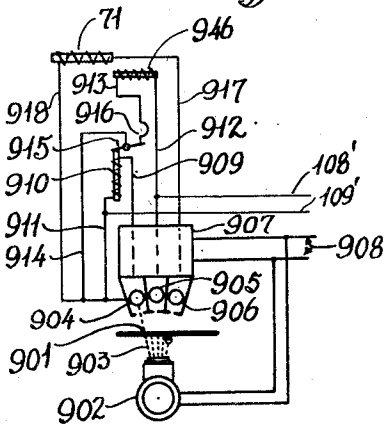


Fig. 14.



INVENTOR.

Marston Lovell Hamlin

Patented Sept. 13, 1949

2,482,061

UNITED STATES PATENT OFFICE

2,482,061

MASTER CLOCK

Marston Lovell Hamlin, Lynbrook, N. Y.

Application May 24, 1943, Serial No. 488,189

16 Claims. (Cl. 58—25)

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This invention relates to a clock comprising an isochronously oscillating member which is undamped at the ends of its excursions and is maintained by short, sharp, banked impulses at substantially the mid points of its excursions, and a counting mechanism which counts in suitable units the number of excursions of the oscillating member and whose action is controlled by said impulses independently of said oscillating member. More particularly the invention relates to a pendulum clock in which short, sharp, banked impulses are applied to the pendulum bob in phase with its swings, the pendulum being entirely free at the ends of its swings, and in which no energy for operating dial works or other counting mechanism is taken from or reacts on the pendulum.

It is one object of this invention to provide a commercial precision clock requiring a minimum of precision operations in its construction.

It is another object of this invention to provide a commercial precision clock containing few and simple moving parts.

It is another object of this invention to provide a clock whose timekeeping shall be in a high degree independent of the mechanical condition and state of lubrication of its works.

It is another object of this invention to provide a commercial precision clock to serve as a master clock or program clock or clock for the control of tower clocks, from which any desired number of signals or control impulses at desired intervals may be taken off without in any degree affecting the rate of the clock.

It is another object of this invention to provide a clock in which a pendulum or other isochronously oscillating system receives a constant impulse of very short duration substantially at the mid point of its excursions and is free of interference at the ends of its excursions.

Other advantages will appear in the following description to those skilled in the art.

Hitherto it has generally been considered desirable in order to avoid disturbing vibrations to apply impulse to a pendulum or other oscillating member used for timekeeping in the form of a gentle pressure of substantial duration, the pressure increasing gradually to a maximum and gradually decreasing during the impulse period. In some forms of escapement, e. g., in the recoil and Graham dead-beat anchor escapements and in the Grimthorpe gravity escapement, the impulse members act on or are acted on by the pendulum during all or the greater part of its swing. In others, e. g., in the Synchronome escapement, the impulse is confined to a fraction, but a substantial fraction of the total swing. In all cases, however, the impulse involves a certain amount of rubbing or rolling friction between the pendulum and other parts of the mechanism for a sensible fraction of the pendulum swing.

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I have found that this friction and relatively prolonged interference with the swing of the pendulum may be avoided without introducing undesirable distortions or vibrations of the pendulum by applying the impulse in the form of a light, practically instantaneous tap to an adequately heavy pendulum bob at or near the mid point of its swing. I have further found that by banking or limiting the fall of the impulse member at a fixed point I may make the impulse self-compensating for minor variations in its velocity or force, thereby maintaining the amplitude of the pendulum substantially constant.

In one embodiment of my invention an impulse is imparted to the bob of a seconds pendulum at every complete swing (i. e., every two seconds) at the center of its swing by a gravity- or spring-loaded impulse member which is periodically released by a trigger pull on the pendulum acting on a light trigger mounted on a detent which engages the impulse member. I have found it practical to have this release occur not more than 10′–15′ of arc from the center point of the swing when the half swing of the pendulum amounts to approximately 1° to 1° 30′ of arc; the duration of the release action is extremely short; the rest of the swing is free of interference except for the nearly instantaneous impulse tap at the center. This interference is not only small and of short duration, but substantially constant in phase and amount. These conditions, viz., minimum constant interference limited to the center portion of the pendulum swing, make for precise timekeeping. Furthermore since the impulse is applied to the bob rather than to the rod, it produces no perceptible distortion of the rod or undesirable vibration.

Several preferred embodiments of my invention are illustrated diagrammatically in the accompanying figures and are described below, but the invention is not intended to be limited thereby.

Figure 1 illustrates the pendulum unit of one embodiment of my invention as seen from the front.

Figure 2 is a section on the line 2—2 of Figure 1.

Figure 3 is a front view of certain details of the impulse and reset mechanism of Figure 1.

Figure 4 is a sectional view on line 4—4 (Figure 5) of a portion of the mechanism shown in Figures 3 and 5.

Figure 5 is a front view of the impulse-member mounting.

Figure 6 is a plan view of the electromagnet pole pieces and armature shown in elevation in Figure 3.

Figure 7 illustrates the back and Figure 8 the front of one form of counting mechanism.

Figure 9 is an elevation of a modified electric maintenance mechanism.

Figure 10 illustrates one method of taking period signals or impulses from a clock embodying this invention.

Figure 11 is a front elevation of a gravity- or spring-operated maintenance device embodying my invention.

Figure 12 is a section on line 12—12 of Figure 11 and indicates diagrammatically its relation to and dial works.

Figure 13 is an elevation and Figure 14 a plan in simplified diagrammatic form of a modified electric maintenance and counting system.

In the drawings the heavy line 1 represents the outline of a case which may be hung on a wall by hanger 2 screwed to an angle-iron bracket 3 inside the case. Two pieces of angle iron 4 are welded to bracket 3 to form a support for threaded stud 5 which turns freely in threaded holes in supports 4. A hook 6, firmly secured to stud 5 by nuts 7, carries jams 8 between which thin steel suspension springs 9 are gripped by screws passing through holes in the springs. A bar 10 also carries jams similarly gripping the lower ends of springs 9.

Pendulum rod 11, made of a low-expansion nickel-steel alloy, is threaded into bar 10 and locked by nut 12. Bob 13 has a hole passing through and perpendicular to its axis through which the lower threaded end of rod 11 passes with a sliding fit. The bob is supported on the rod by rating nut 14, locked by nut 15. Numbers 16 and 17 indicate small shelves fixed on rod 11, on which rating weights may be placed. A pointer 18 on the lower end of the rod and scale 19 fixed to case 1 indicate amplitude of pendulum swings.

A metal panel 20 carries the maintenance gear for keeping the pendulum swinging. At its right-hand end it rests on fixed stud 21 against which it is held by spring 22. At its heavier left-hand end it is supported by adjusting nut 23 bearing on bracket 24' fixed to panel 20; nut 23 is threaded on low-expansion-alloy rod 24 which at its lower end passes through a hole in bracket 24' and at its upper end is fixed in bracket 3. Fixed studs 25 carry spring clips 26 which keep panel 20 in vertical alinement while permitting vertical adjustment by nut 23, and horizontal adjustment by means of jaws 27 and 28 engaging stud 21 and independently pivoted on stud 29 fixed in panel 20. Jaw 27 is pressed against stud 21 by tension spring 30, while jaw 28 is pressed against the other side of stud 21 by adjusting screw 31 threaded through a stud fixed in panel 20.

The impulse and reset gear is indicated in general at 40 in Figure 1 and shown in greater detail in Figures 3–6.

An impulse member 41, pivoted at 42 on a two-part brass arbor, carries detent arm 43 engaging detent 44. On one part of arbor 42 is fixed the inner end of spring 45, the outer end of which is fixed to stud 46 adjustably mounted by an arm 47 on panel 20. Member 41 also carries cam 48 on its upper portion. Member 41 is adapted to engage anvil 41' carried by bob 13 when 41 is in its released position, but is high enough in its raised position to clear 41' as the pendulum swings.

Fixed to member 41 and rotating with it is mercury switch 50 containing a drop of mercury 51 and filled with hydrogen. Electrodes 52 are sealed into one end of switch 50 and are connected with leads 53 and 54.

Lead 53 is electrically connected to impulse member 41 by screw 55 and is thereby grounded to panel 20 through spring 45 and arm 47 and their respective mountings which are of brass. Lead 54, which is stiff enough to be self-supporting is electrically connected to the outer end of flexible spiral conductor 56, which is advantageously a ribbon of brass shim stock 0.001 inch thick. The spiral conductor at its inner end is connected with wire mount 57 carried by brass plate 58 connected with lead 103.

Posts 60 mounted in panel 20 carry outer brass plate 63 in which outboard pivot 42 is mounted by means of adjustable bearing 64 threaded into the plane and locked by nut 62.

Brass plate 58 is mounted on Bakelite block 59 which is mounted on plate 63. Lead 103 is thus insulated from panel 20 which serves as ground. Part of outer plate 63 is omitted in Figure 3 for greater clarity.

Adjustable banking screw 61 threaded into stud 62 mounted on panel 20 limits the movement of impulse member 41 by contact with detent arm 43.

The impulse-reset mechanism comprises electromagnet 70 with coil 71 and pole pieces 72 adapted to attract armature 73. The latter is carried on a rocking member pivoted at 74 on an arbor supported between panel 20 and a front plante 80. This member consists of a central brass block 75 and four perpendicular arms 76 fixed in the block; three of these arms carry adjustable balancing and inertia weights 77. The lower arm 76 also carries a small stud 78 screwed into the arm perpendicular to the plane of the diagram and adapted to engage cam 48 when impulse member 41 is in its released position. Adjustable banking pins 81 and 82 limit the rotation of the rocking member.

Electrical energy to operate the clock is provided by storage battery 100 (Figure 1), connected to the clock by leads 101 and 102. Lead 103 connects lead 101 with mercury switch 50; lead 104 is connected with magnet coil 71 and with panel 20 to which the switch is grounded by lead 53, and thus connects the switch with magnet coil 71. A condenser 105 to suppress sparking in the switch 50 bridges leads 103 and 104. Lead 106 from magnet coil connects with lead 102 through variable resistance 107.

Leads 108 and 109 connect leads 104 and 102, the latter through variable resistance 110, with the counting mechanism of the clock, i. e., the dial works, described below and shown in Figures 7 and 8.

Impulse member 41 is maintained in the position shown by contact of arm 43 with detent 44. The latter is pivoted at 85 and the upper arm held as shown against banking pin 86 by hair spring 87. A small face plate 88 supports the outer pivot 85 and is carried by back plate 88' which supports the inner pivot. Plate 88' is adjustably mounted on panel 20 by screw 89.

The lower portion of detent 44 carries trigger 90 pivoted on the detent at 91. An upper projection of the trigger engages lower radial arm of the detent. The trigger is thus free to pivot in a clockwise direction, but on being moved in a counterclockwise direction it carries detent 44

with it. The trigger normally hangs in a vertical position as shown.

Horizontal rod 92 is adjustably mounted on rod 11 and carries adjustably mounted trigger pull 93.

The various adjustments having been properly made, operation of the isochronous or pendulum unit of the clock is as follows:

Assume the pendulum set in motion manually and swinging from its center position to the left. Trigger pull 93 pushes aside trigger 90 and lets it fall without disturbing detent 44; the pendulum completes its excursion to the left undisturbed. On its return trigger pull 93 again engages trigger 90 and moves it to the right. This time, however, the trigger carries the detent 44 with it by virtue of the engagement of the upper projection of the trigger with the lower radial arm of the detent, until the trigger falls off the trigger pull and the detent is again forced back lightly against banking pin 86 by spring 87.

This movement of the detent releases arm 43, so that impulse member 41 falls towards anvil 41' urged by spring 45, and is stopped at the end of its motion by contact of arm 43 with banking screw 61.

If pendulum is swinging with correct amplitude, impulse arm 41 strikes anvil 41' horizontally at center of pendulum swing, and at the same time arm 43 strikes banking screw 61. If excursion of pendulum is too wide, its velocity at center of swing will be greater, so that it will have passed center point before impulse arm is arrested by banking screw; consequently arm 41 will not strike anvil 41' before pendulum passes center point and arm is arrested by banking screw. The pendulum thus receives no impulse and its amplitude is lessened. On the other hand if the excursions are too small, velocity will be less, and arm 41 will strike anvil 41' before pendulum passes center point. The spring 45 is adjusted to furnish slightly more impulse than is needed for maintaining the oscillations of the pendulum; consequently the amplitude of its swing will increase until the excess impulse energy is absorbed by pin 61. Furthermore when the bob is moving faster, if struck by impulse arm it will absorb less energy, and when moving slower more energy from impulse arm which always moves at the same rate.

As will be seen from the above, the pendulum will take just sufficient energy from impulse arm 41 to maintain its swings at substantially constant amplitude, or will average out small variations and thus avoid any cumulative error.

As impulse arm 41 falls and arm 43 swings towards the horizontal, mercury drop 51 rolls against electrodes 52 and closes the circuit to electromagnet coil 71 from battery 100 by leads 101, 103, 54, 53, ground through panel, leads 104 and 106 through resistance 107 and lead 102 and auxiliary connections described.

On being energized, magnet 70 sharply attracts armature 73. This results in stud 78 being thrown smartly against cam 48 with sufficient force, by virtue of the inertia of weights 77, to reset arm 43 on detent 44 (which after being pushed aside is restored to locking position by spring 87), while drop 51 rolls away from electrodes 52, thus opening the circuit. Lower rocker arm 76 falls back by gravity against banking pin 82 owing to the adjusted balance of weights 77, and the cycle is ready to be repeated.

It will be seen that the impulse supplied to the pendulum is substantially constant and entirely independent of current strength provided only that there is sufficient current to operate. The impulse assembly (41, 43, 48, 50) and the detent assembly (44, 90) are of very light construction and springs 45 and 87 are relatively weak, so that friction on pivots 42 and 85 and between trigger pull 93 and trigger 90 is very small. Little change takes place in the operation of these units over extended periods of time. The impulse is independent of the mechanical condition and state of lubrication of most of the mechanism, i. e., of the reset mechanism above described and the counting mechanism described below, the only requirement being that they be in sufficiently good condition to operate.

The impulse arm may be gravity-loaded by appropriate weighting, and spring 45 may then be dispensed with.

For the most refined work pivots 42 and 85 may be mounted in jeweled bearings, trigger 90 and/or trigger pull 93 may be jewelled and springs 45 and 87 may be made of Elinvar or similar alloy of low temperature-stiffness coefficient.

In the counting mechanism (Figures 7 and 8) three hands 201, 202 and 203 show respectively hours, minutes and seconds. They are of the jump type, i. e., the hour hand moves only at the end of each hour and then moves forward an hour interval on the dial, the minute hand moves similarly each minute and the second hand each second. These hands are carried on arbors 201', 202' and 203' pivoted in plate 204 and in bridge plates omitted from the drawings for clarity.

Each arbor carries fixed to it a toothed wheel, respectively 205, 206 and 207. Wheel 205 has 24 teeth, and wheels 206 and 207 60 teeth each. On each of the two latter wheels is fixed a spiral cam 208 and 209.

A half-second compound pendulum 210 with upper and lower bobs is mounted on pivoted arbor 211 which carries fixed to it armature 212. When the pendulum swings the armature swings alternately into line with and away from poles 213 of an electromagnet (shown partially cut away in the drawing) which is mounted to the rear of wheel 207 by means of posts screwed into plate 204.

A gathering pawl 214 is pivoted on armature 212. Its lower end is adapted to engage the teeth of wheel 207. Pivoted at 215 on pawl 214 are two links 217 and 218. Slots in the outer ends of the links embrace fixed pins 219 and 220 so that the links are capable of a limited sliding and rotational motion on the pins. The lengths of the links and the positions of the pins are such that they permit pawl 214 to engage and gather one and only one tooth of wheel 207 at each complete oscillation of pendulum 210 (when it oscillates through a sufficient angle), regardless of how great the amplitude is beyond the required minimum.

An electric impulse is transmitted once every two seconds by leads 108 and 109 to the coil 213' (shown partly cut away) of the electric magnet provided with pole pieces 213, the periodicity being precisely controlled by the above described movements of the mercury switch 50, which is controlled in turn by the swings of pendulum 11, 13.

The bobs of pendulum 210 are adjusted to give it an approximate ½-second rate (one complete swing each second); accordingly the electric impulses arriving at exactly two-second intervals energize pole pieces 213 at exact two-second intervals, thereby setting in oscillation the compound pendulum 210 and maintaining it in syn-

chronism with but at twice the rate of the main pendulum 11, 13. The inertia of the bobs of pendulum 210 is sufficient to keep it swinging eight or ten times even if the electric impulses should be temporarily discontinued.

Since the ½-second pendulum makes a complete swing each second, the attached gathering pawl 214 advances wheel 207 one tooth or 1/60 revolution each second, and accordingly associated hand 203 indicates seconds on its dial (Figure 8). Spring-tensioned pawl 221, bearing on the teeth of wheel 207 prevents overrunning and retrograde movements of the wheel.

The left end of rocker arm 225 (viewing Figure 7) pivoted at 226 is pressed lightly against cam 209 by spring 227, which draws up the left end of rocker arm 228 against stud 229 on the right end of rocker arm 225. Rocker arm 228 is pivoted at 230; at its right end it carries spring-tensioned pawl 231 which engages teeth of the minute wheel 206; it also carries fixed stop 232 which engages the teeth of wheel 206 and prevents overrunning of the wheel on completion of a downward stroke of this end of the rocker arm.

As wheel 207 is rotated, cam 209 raises the left end of rocker arm 225 and depresses its right end. Stud 229 accordingly depresses the left end and raises the right end of rocker arm 228. As wheel 207 rotates hand 203 to the 60-second point, arm 225 falls off the end of cam 209, and spring 227 rocks arm 228, depressing pawl 231 and advancing minute wheel 206. The lift of cam 209 and the lengths of arms 225 and 228 are so chosen that pawl 231 gathers one and only one tooth of wheel 206 in each cycle of operation of the rocker arms. Accordingly hand 202 is advanced one minute on its dial each time hand 203 reaches the 60-second mark. Spring-tensioned pawl 233 bearing on the teeth of wheel 206 prevents retrograde movement of the wheel.

Similarly the rotation of wheel 206 and spiral cam 208 advances wheel 205 by means of rocker arms 235 and 238, pivoted at 236 and 237, tension spring 239 and spring-tensioned pawl 240 engaging the teeth of hour wheel 205. In this case, however, the lift of cam 208 and the lengths of the arms 235 and 238 are so chosen as to advance wheel 205 1/24 revolution each cycle. Accordingly associated hand 201 indicates hours on its 24-hour dial. Spring-tensioned pawl 241 bearing on the teeth of wheel 205 prevents overrunning and retrograde movement of the wheel.

The embodiment illustrated in Figure 9 is in general similar to the embodiment illustrated in Figures 3 and 6, but differs from the latter chiefly in that the reset lever (*a*) is balanced to reset the impulse member by gravity after each impulse, (*b*) is released to do this by the contact of a com on the impulse member with a detent lever, and (*c*) is restored to its raised position by an electromagnet. The magnet is controlled by a mercury switch operated by a forked arm on an extension of the reset lever. Instead of a mercury switch various types of mechanical switch can be used.

This form of the invention has more moving parts than that shown in Figure 3 but has the advantage that the impulse member, having no mercury switch and thus being considerably lighter in weight, acquires greater angular acceleration from a comparatively weak spring. This lessens the interval between trigger pull and impulse and brings the trigger pull proportionately nearer the center point of the pendulum swing.

In the drawing for the sake of simplicity and clarity certain details identical with those in Figure 3 have been omitted. Identical parts in Figures 3 and 9 are indicated by identical reference characters and have the same functions in both embodiments.

Construction and operation of this escapement are as follows: Trigger pull 93, trigger 90 and detent 44 function as in Figure 3. Impulse member 340 differs from impulse member of Figure 3 in carrying no switch and in having a cam 348 differently located from cam 48; it is pivoted at 42 between plate 363, mounted on studs 60 and metal panel 20. Detent lever 341 is pivoted at 342 between plate 343 and panel 20; its lower arm is heavier than its upper and consequently it normally rests on stop 344. At its lower end lever 341 carries a short perpendicular pin 345 projecting into the plane of cam 348. At its upper end lever 341 engages projection 379 on body 375 of reset lever.

The reset lever, pivoted at 74, is weighted by weight 377 on arm 76 so that, when released, it tends to rotate clockwise till stopped by banking pin 382.

The lower portion of body 375 carries curved arm 379 in a plane parallel to panel 20 but on the opposite side of impulse member 340 from the panel. At its lower end it carries pin 379' extending perpendicularly towards panel 20 into the plane of impulse member 340.

At the upper portion of body 375 are affixed armature 73 (constructed and functioning as in Figure 3) and extension arm 376 with fork 378 at its upper end adjusted to operate mercury switch 350 as described below.

Switch 350 contains a drop of mercury 351 adapted to close the circuit between two electrodes 352 when the electrode end of the switch is depressed. The switch is carried in a clip pivoted at 355 between panel 20 and a small plate 356; the latter carries brackets with limit screws 357 threaded in them to adjustably control extent of movement of the switch. Rigidly fixed to the switch clip is arm 353 carrying perpendicularly fixed pin 354 positioned to be engaged by arms of fork 378. The electrodes 352 are respectively connected to extremely flexible leads 303 and 304, e. g., helical ribbons of 0.001 inch brass shim stock. Lead 304 is grounded to panel 20, to which lead 104 is connected, while lead 303 is connected to lead 103 at post 103' insulated from panel 20.

When arm 43 is released and arm 41 delivers its impulse to anvil 41' (as described in connection with Figure 3), cam 348 strikes pin 345 thus rotating lever 341 slightly clockwise and disengaging its upper end from projection 379 on body of reset lever. This permits the reset lever to rotate clockwise on its axis 74 under influence of weight 377, thereby bringing pin 379' into contact with the upper part of impulse arm 41. This forces entire impulse member 340 to rotate clockwise and resets arm 43 on detent 44 as described in connection with Figure 3. Simultaneously upper arm 376 moves to the right, bringing the left finger of fork 378 into contact with pin 354 on arm 353 of switch clip and rotating switch 350 counterclockwise sufficiently to cause mercury drop to roll to electrode end of switch. Reset lever comes to rest when arm 76 strikes banking pin 382.

Contact of mercury with the electrodes closes

circuit with battery 100 through electromagnet coil 71 by means of leads 101, 103, 303, 304, 104, 106, 102 and auxiliary connections described. Energizing of magnet 70 in this way attracts armature 73, thus rotating reset lever counterclockwise on its axis 74 until projection has risen past top of detent lever 341. Banking pin 381 limits rotation in this direction by contact with arm 76. Simultaneously the right arm of fork 378 strikes pin 354, rotating switch 350 clockwise to position shown in the figure, thereby opening circuit to magnet coil 71. The reset lever being freed of the attraction of the magnet, falls back slightly till held by contact of projection 379 on end of detent lever 341, as shown in Figure 9.

The distances, inertias and magnetic attraction are made such that the time required for this cycle of operations is only a small fraction of that needed for a complete swing of pendulum 11, 13. Accordingly the impulse mechanism is in postion to repeat the cycle at each swing of the pendulum, and oscillations of the pendulum are thereby maintained.

A counting mechanism or dial works of desired design is connected in parallel with coil 71 by leads 108 and 109 as illustrated in Figure 1, and thereby indicates time as previously described. The dial works may advantageously have the form shown in Figures 7 and 8.

Alternatively by suitable changes in magnet coils and resistances in well known ways, the counting mechanism may be connected in series with coil 71.

When it is desired to use the clock of this invention for transmitting periodic signals, a separate battery or other source of electric current 1000 (Figure 10) may be provided, connected by one lead with a suitable signal or electrical impulse transmitter 1001. Arbors such as 201', 202' and 203' of the dial works, electrically insulated from each other, carry respectively contact arms 1201, 1202 and 1203, adapted on rotation of the arbors to make contact with adjustably fixed spring contact arms 1211, 1212 and 1213. Transmitter 1001 is connected by a lead and wiping contact with arbor 201'. Spring contact arm 1211 is similarly connected with arbor 202' and spring arm 1212 with arbor 203'. Spring arm 1213 is connected by the other battery lead with battery 1000. The three contacts, the battery and the transmitter are thus connected in series. As the contact arms mounted on the arbors 201' 202' and 203' rotate in the direction of the arrows they periodically make contact with the spring arms 1211, 1212 and 1213, arm 1201 once in 24 hours for 1 hour, arm 1202 once an hour for 1 minute, and arm 1203 once a minute for 1 second. Since all contacts must be closed to transmit a signal, the arrangement described will transmit a signal of 1 second's duration once every 24 hours. In the diagram this will occur at $00^h00^m00^s$ to $00^h00^m01^s$.

By suitably altering the position of fixed arms 1211, 1212 and 1213 angularly around the respective arbors, the time at which the signal occurs may be altered at will in one-second steps.

If only a momentary signal is desired arm 1213 may be adjusted so that arm 1203 contacts it only between two second stations, e. g., between 14 and 15 seconds.

Signals at other intervals may be transmitted by similar arrangements in ways readily understood by those skilled in the art. For example, by short-circuiting the contact on the 24-hour arbor 201', the arrangement shown will transmit one-second signals once an hour; by doing this and also providing four spring contact arms electrically connected in parallel and spaced 90° apart around hour arbor 202', one-second signals will be given every 15 seconds. An almost unlimited variety of signals, both as to duration and timing, is thus possible by using suitable connections and contacts.

The signals or electrical impulses thus sent may be used to operate lights or bells, to control process cycles, actuate or control machinery, tower clocks, secondary clocks and the like by suitable relays, amplifiers or other devices well known to the art.

The important feature that these various methods and means of signal transmission have in common is that, in contradistinction to many previously suggested signaling methods, those described have no effect on the running rate of the clock. This is because, as pointed out above, the operation of the dial works or counting mechanism does not in any way react on the operation of the pendulum, regardless of the particular type of counting mechanism used or the particular form or motive power chosen within the scope of my invention.

Figure 11, a cut-away front view, and Figure 12, a side view partly in section, represent another embodiment of my invention in which a pendulum is maintained in oscillation and its swings counted by mechanical instead of electrical means.

In these figures 11 is the pendulum rod, 13 the bob, and 41' the anvil; 20 is the panel supporting the maintaining gear 400. Trigger-pull 93 is adjustably fixed on rod 92 mounted adjustably on rod 11. Detent 44 pivoted at 85, banking pin 86, spring 87 and trigger 90 pivoted on detent 44 at 91 function as in the first described embodiment.

A weighted impulse member 410 is mounted on arbor 420 pivoted between face plate 401 and back plate 402. Face plate 401, of the same size and shape as back plate 402, is omitted in Figure 11 for clarity. Detent arm 430 is formed integral with member 410, as is reset arm 480. In the position shown detent arm 430 engages detent 44, holding member 410 in a raised position above the path of swing of anvil 41' and bob 13.

An escape wheel 760 is mounted on arbor 740 pivoted between plates 401 and 402. The latter are held in spaced relationship to each other and also mounted on panel 20 by posts 403. Escape wheel 760 carries three radial teeth 761 and three rearwardly extending pins 762. On rotation of the escape wheel the teeth in turn engage one end of detent 500 pivoted at 501; the other and heavier end of the detent carries adjusting screw 700 adapted to engage detent arm 430 when the latter is released by detent 44. Banking pins 502 and 503 limit the movement of detent 500. Pins 762 are adapted to engage arm 480 when detent arm is released and when escape wheel revolves.

Arbor 740 also carries fixed on it bevel gear 801 meshing with bevel gear 802 fixed on vertical shaft 803; the latter is rotatably mounted in brackets 804. Shaft 803 is connected, as by a universal joint, with shaft 806. The latter is connected with any suitable type of conventional clockwork, dial, hands, etc., indicated at 806', to which power is continuously applied by spring, weight or other means. The direction of rotation impressed on the clockwork by this means is such as to force escape wheel 760, as seen in Fig-

ure 11, in a counterclockwise direction. The gear ratios are such that the hands of the clockwork are advanced six seconds for each full revolution of escape wheel 760. The clockwork and its connections are of conventional type well understood by those skilled in the art and require no further description.

The operation of this mechanism is as follows: When the pendulum swings to the left (viewing Figure 11) after being set manually in motion, trigger pull 93 raises and drops trigger 90 without moving detent 44, as described in connection with Figure 3. On the return swing the trigger pull momentarily pulls aside trigger 90 and detent 44, releasing detent arm 430. This permits weighted impulse arm 410 to fall, striking anvil 41' and imparting an impulse to bob 13, the timing being so adjusted that this occurs at the center of the swing. The weight on arm 410 is chosen so as to furnish slightly more energy on striking anvil 41' than is required to maintain the oscillations of the pendulum. The fall of member 410 causes arm 430 to rise and strike adjusting screw 700, raising it and depressing opposite end of detent 500. This action of the detent releases escape wheel 760, which rotates counterclockwise, being propelled by the force transmitted through gears 801 and 802 and shafts 803 and 806 from the above-mentioned clockwork.

Rotation of the wheel brings one of the pins 762 to bear on arm 480 and forces it to the right, thereby raising weighted member 410 again to the position shown in Figure 10 and resetting arm 430 on detent 44. As arm 430 is forced down, screw 700 falls, thus raising the opposite end of detent 500 which engages the next tooth of the escape wheel and arrests its rotation.

From this description it will be seen that on each full swing of the pendulum, its bob receives an impulse from member 410, and escape wheel 760 rotates one third of a turn, at the same time resetting the impulse member. Since the pendulum is a seconds pendulum, this cycle occurs every two seconds and wheel 760 completes a rotation every six seconds. Accordingly the hands of the clockwork referred to above, which advance six seconds with each revolution of wheel 760, indicate correct time intervals.

The banking effect of pin 502 through detent 500 and screw 700 on arm 430 operates to lessen or prevent an impulse being imparted by member 410 to anvil 41' in case the pendulum is momentarily swinging too wide so that its angular velocity at the center of its swing is greater than normal. This absence of or reduction in the impulse soon reduces the amplitude of the pendulum swing. On the other hand if the pendulum is not swinging wide enough, the angular velocity of the bob is less at the center of the swing, and member 410 strikes anvil 41' slightly earlier in the swing; this lengthens the duration of the impulse and increases the amplitude of the pendulum. Furthermore the faster the bob moves the less energy, and the slower it moves the more energy it absorbs from the impulse member, which always falls at a constant rate. These actions are similar to those described in connection with the first embodiment and similarly tend to keep the arc of swing of the pendulum constant.

Another embodiment of my invention is illustrated diagrammatically in Figures 13 and 14. In this embodiment the pendulum is entirely free of mechanical contact with the maintaining gear except for the nearly instantaneous tap of the impulse arm 810 every two seconds on anvil 41' at the exact center of the pendulum swing.

The lower end of rod 11 is provided with a lightweight opaque screen 900 pierced by a slot 901. The screen intercepts light beam 903 from lamp 902 which is focussed on three photoelectric cells 904, 905 and 906. As the pendulum swings, however, slot 901 permits beam 903 momentarily to illuminate the three photoelectric cells in turn. Consider a swing from left to right. Cell 904 is first energized by the beam; current passes through it and is amplified by amplifier 907, which may be of any suitable commercially available type and is powered by current source 908; current passes through lead 909, electromagnet coil 910 and return lead 911. The coil 910 is part of a relatively slow-acting relay and when it is energized the magnet attracts pivoted armature 915, causing it to close the gap between its end and spring contact 916. Owing to the slow action of this relay, this gap remains closed while slot 901 illuminates cell 905 a fraction of a second later, causing current to pass through lead 912, electromagnet coil 946, lead 913, contact 916, armature 915, and return lead 914. Magnet 946 attracts armature 945 forming upper radial arm of detent 944 pivoted at 950. This releases detent arm 830, integral with gravity-loaded impulse arm 810 and return cam 880, pivoted at 820, so that impulse member falls and arm 810 strikes anvil 41', thereby maintaining the swing of the pendulum as described in connection with first-disclosed embodiment; in the present embodiment also banking screw 61 functions, by contact with arm 830, to limit drop of impulse member and thus keep the swings of pendulum 11, 13 substantially constant. Positions of slot 901, lamp 902 and cell 905 are so adjusted that the impulse occurs at the center of the pendulum swing.

As the swing of the pendulum continues, relay 910—915—916 opens, cells 904 and 905 are darkened and detent 944 is returned to its original position by a spring not shown.

Finally slot 901 illuminates cell 906, which is so located that this occurs at the extreme right of the pendulum swing. Current then flows through lead 917, electromagnet coil 71 and return lead 918. Energizing coil 71 causes magnet 70 to attract armature 73, thus rocking associated reset lever pivoted at 74 and resetting detent arm 830 on detent 944 by contact of stud 78 with reset cam 880.

On the return swing, when cell 905 is illuminated, no current passes through magnet coil 946, since gap between armature 915 and contact 916 is open. Accordingly impulse member is released only on left-to-right swings of the pendulum.

The counting mechanism associated with a pendulum of this type may be operated in numerous ways, for example by a circuit 108' and 109' in parallel with coil 946, or by an independent circuit and photoelectric cell.

A pendulum of this type absorbs only sufficient energy to overcome the friction of passage through air and of the flexing of its suspension springs and gives up no appreciable energy in releasing the impulse mechanism; it is advantageously operated in a constant-temperature and constant-pressure container or case.

It will be seen that in all the embodiments of my invention described above an isochronously oscillating member is kept oscillating by almost instantaneous impulses imparted to it substantially at the mid point of its excursions by an impulse member whose impulse strokes are banked

or limited by a fixed stop so positioned that abnormally wide excursions of the oscillating member partly or entirely escape the normal impact of the impulse member. In this way abnormally wide oscillations quickly diminish to normal amplitude. Abnormally short excursions of the oscillating member are increased by reason of the resulting longer time of contact of the impulse member with the oscillating member; furthermore I prefer to reinforce this action by providing a slightly more energetic impulse than is required to maintain normal oscillations, the excess energy being absorbed by impact of the impulse member with the fixed stop.

A counting or time-indicating mechanism is preferably associated with the impulse member in such a way that its indications are controlled solely by the action of the impulse member but in strict synchronism with the oscillating member. Thus no energy is absorbed by the counting mechanism from the oscillating member nor does the former react on the latter. Accordingly the isochronism of the oscillating member is not disturbed by the functioning of the counting or time-indicating mechanism.

While it is desirable from the viewpoint of consistent timekeeping to limit any necessary interference with an isochronously oscillating member—e. g., release of impulse member and impulse—to positions as close as possible to the mid point of the oscillations, some deviation from this practise is possible for many purposes without serious practical disadvantage. The chief requisite is to keep the oscillating member free of interference at the ends of its oscillations, but it is further preferable to confine such interference to the central portion of the oscillations. For example, in the embodiments shown in Figures 3 and 9 adjustments may be made so that the impulse occurs at substantially the mid point of the pendulum swing and the release occurs a necessary fraction of the arc before the impulse, or so that the release and impulse occur on opposite sides of the mid point of the swing. For many purposes good results are had if the impulse occurs not more than ¼ the half swing away from the mid point; in the claims I have used the phrase "at approximately the mid point" in this sense.

I claim:

1. A clock comprising an isochronously oscillating pendulum having a bob, an anvil fixedly associated with the pendulum at a point not remote from the bob and having an impact face normal to the path of travel of the bob, an impulse member adapted to deliver an impact of only substantially instantaneous duration to the impact face of said anvil at approximately the mid point of the oscillations of the pendulum when the impulse member is released from a biased position, a detent adapted to retain the impulse member in its biased position, a trigger on the detent adapted to release the impulse member by displacement of the detent when moved in one direction but free to move in the other direction without action on the detent, a trigger-pull mounted on the pendulum adapted to engage the trigger, a banking stop adapted to limit the impulse stroke of the impulse member in fixed relation to the oscillations of the pendulum, a powered reset means adapted when operated to contact the impulse member in its released position and reset it to its biased position, means associated with the impulse member to cause the reset means to operate after each release of the impulse member, and powered time-indicating means controlled by the action of the impulse member to indicate time in synchronism with but without reaction on the pendulum.

2. A clock as defined in claim 1 in which the reset means and the time-indicating means are electromagnetically powered, a source of electric current, leads connecting the current source in circuit with the reset means and the time-indicating means, a common switch controlling passage of current to the reset means and time-indicating means, said switch being responsive to the action of the impulse member.

3. A clock as defined in claim 2 in which the reset means and the time-indicating means are electromagnetically powered and controlled by a common oscillatory mercury switch having an operating angle independent of the angle of swing of the pendulum, said switch being pivotally mounted on fixed bearings and operated by a pivoted arm responsive to the action of the impulse member.

4. A clock as defined in claim 2 in which the impulse member is an oscillating member and the reset means and time-indicating means are electromagnetically powered and controlled by a common mercury switch mounted on and oscillating with the impulse member.

5. A clock as defined in claim 1 in which the reset means comprises an escape wheel having an element adapted to engage the impulse member when released from its biased position and on rotation of the escape wheel to reset the impulse member to its biased position, and in which mechanical operating means connects said escape wheel with the time indicating means, whereby rotation of the escape wheel is accompanied by actuation of the time-indicating means.

6. A program clock comprising an isochronously oscillating pendulum, an impulse member adapted to deliver an impact of only substantially instantaneous duration to a point on on near the bob of said pendulum at approximately the mid point of its oscillations when the impulse member is released from a biased position, a detent adapted to retain the impulse member in its biased position, a trigger on the detent adapted to release the impulse member by displacement of the detent when moved in one direction but free to move in the other direction without action on the detent, a trigger-pull mounted on the pendulum adapted to engage the trigger, a banking stop adapted to limit the impulse stroke of the impulse member in fixed relation to the oscillations of the pendulum, a powered reset means adapted when operated to contact the impulse member in its released position and reset it to its biased position, means associated with the impulse member to cause the reset means to operate after each release of the impulse member, powered time-indicating means controlled by action of the impulse member to indicate time in synchronism with but without reaction on the pendulum, said time-indicating means having at least one arbor rotating in timed relation to but without reaction on the oscillations of the pendulum, and signal means actuated by rotation of the arbor.

7. A combination comprising a pendulum having a bob, means for maintaining oscillations of the pendulum solely by delivering successive substantially instantaneous impacts to an impact face of the bob at an intermediate point not remote from the mid point of its oscillations, said impact face being a plane surface normal to the path of travel of the bob, means responsive to

travel of said pendulum at an intermediate point in its oscillations for effecting operation of said impact delivering means, whereby said pendulum is free of interference at the ends of its oscillations, and means responsive to movement of said impact-delivering means for restoring said impact-delivering means to condition for delivering another impact to said bob during a subsequent oscillation of said pendulum.

8. The combination comprising a pendulum having a bob adapted to swing in a predetermined path, an impact-delivering member pivoted to swing in another path, the path of said pendulum bob at an intermediate point of its swing intersecting the path of said member, means responsive to movement of said pendulum at an intermediate point of its swing for effecting actuation of said member to deliver an impact of only substantially instantaneous duration to said bob at an intermediate point of its swing and means responsive to movement of said member for restoring it to a position out of the path of said bob for delivering another impact to said bob.

9. A clock comprising a pendulum with a bob, a pivoted impulse member adapted to deliver from a biased position an impact of only substantially instantaneous duration to said bob at approximately the mid point of its swings, a movable detent member including a trigger adapted to retain said impulse member in its biased position, said trigger being movably mounted on said detent and adapted only when pulled in one direction to move said detent to release said impulse member, a trigger-pull on said pendulum adapted to move said trigger in its operative direction at a point in the pendulum swing not further removed from the center of swing than about ¼ the half swing, a mercury switch mounted to swing with the impulse member and close a circuit when the member is in its released position, a banking stop positioned to limit the impact movement of the impulse member in fixed relation to the pendulum swings, a pivoted reset lever adapted when operated to reset the impulse member to its biased position, inertia weights on said reset lever balanced to urge said lever to a non-operative position, an armature on said reset lever, an electromagnet adapted when energized to attract said armature and thereby bring the reset lever into operative position to reset said impulse member to its biased position, an electromagnetically operated time-indicating means, a source of electric current, and electric leads connecting said source with said mercury switch, said electromagnet and said time-indicating means, whereby after each operation of said impulse member it is reset to its biased position and the time-indicating means operates in synchronism with but without reacting on the pendulum.

10. A clock comprising a pendulum with a bob, a pivoted impulse member adapted to deliver from the biased position an impact of only substantially instantaneous duration to said bob at approximately the mid point of its swings, a movable detent member including a trigger adapted to retain said impulse member in its biased position, said trigger being movably mounted on said detent and adapted only when pulled in one direction to move said detent to release said impulse member, a trigger-pull on said pendulum adapted to move said trigger in its operative direction at a point in the pendulum swing not further removed from the center of swing than about ¼ the half swing, a banking stop positioned to limit the impact movement of the impulse member in fixed relation to the pendulum swings, a pivoted reset lever adapted when operated to reset the impulse member to its biased position, biasing means associated with said reset lever to urge it to an operative position, a retaining means on said reset lever, a detent lever adapted to engage the retaining means on the reset lever to hold the reset lever in non-operative biased position, means on the impulse member adapted when the impulse member is in released position to disengage said detent lever from said retaining means thereby releasing the reset lever to move to an operative position and reset the impulse member to a biased position, an armature on the reset lever adapted when attracted to move the reset lever to a biased position in which it is retained by the detent lever, an electromagnet adapted when energized to attract said armature thereby moving it to its biased position, an electric switch, an arm on said reset lever adapted to open said switch when the reset lever is in biased position and close it when the reset lever is in operative position, a source of electric current, an electromagnetically operated time-indicating means and electric leads connecting said source with said switch, said electromagnet and said time-indicating means, whereby after each operation of said impulse member it is reset to its biased position and the time-indicating means operates in synchronism with but without reacting on the pendulum.

11. A clock comprising a pendulum with a bob, a pivoted impulse member adapted to deliver from a biased position an impact of only substantially instantaneous duration to said bob at approximately the mid point of its swings, a movable detent member including a trigger adapted to retain said impulse member in its biased position, said trigger being movably mounted on said detent and adapted only when pulled in one direction to move said detent to release said impulse member, a trigger-pull on said pendulum adapted to move said trigger in its operative direction at a point intermediate the ends of the swings of the pendulum, an escape wheel provided with detaining and reset means, the reset means being adapted on rotation of the wheel to engage the impulse member in its released position and move it to its biased position, a detent lever adapted in its equilibrium position to engage said detaining means and prevent rotation of the escape wheel and adapted to be moved from its equilibrium position by movement of the impulse member to its released position thereby permitting rotation of the escape wheel, banking means adapted to limit movement of the detent lever and the impulse member, powered time-indicating means, and mechanical means connecting the time-indicating means with the escape wheel and reversibly applying torque to the latter, whereby the powered time-indicating means furnishes energy for maintaining the oscillations of the pendulum and is controlled in its indications to synchronize with but not react on the oscillations of the pendulum.

12. A combination comprising an isochronously oscillating pendulum, impulse means adapted to deliver an impact of only substantially instantaneous duration to a point not remote from the bob of the pendulum at an intermediate point in its oscillations, means responsive to oscillations of the pendulum for effecting operation of the impulse means without reaction on the pendulum at the ends of its oscillations, and means for re-

storing the impulse means to condition for delivering another impact to the pendulum.

13. A clock comprising an isochronously oscillating pendulum, maintaining gear, and time-indicating means; said maintaining gear comprising an impulse member adapted to maintain the oscillations of said pendulum solely by delivering a series of timed substantially instantaneous horizontally directed impacts to the bob of the pendulum at an intermediate point in its oscillations when the impulse member is released from a biased position, a detent adapted to retain the impulse member in its biased position and periodically to release it from its biased position in response to the travel of the pendulum, a banking stop adapted to limit the impulse stroke of the impulse member in fixed relation to the oscillations of the pendulum, and powered reset means for restoring the impulse member to its biased position after each impact, said maintaining gear being without reaction on the pendulum at the ends of its oscillations; and said time-indicating means comprising counting means responsive to the action of said maintaining gear but without reaction on said impulse member or said pendulum.

14. In combination, a pendulum having a bob, an impulse member having an impact portion and a detent portion, a detent member including a trigger engaging said detent portion to maintain the impact portion out of the path of the pendulum during movement of the pendulum in one direction, said trigger being movably mounted on said detent and adapted to engage a portion of the pendulum during its movement in said direction without effecting release of said detent portion by said detent but adapted upon movement of the pendulum in the reverse direction to engage said portion of the pendulum to effect release of said detent portion by said detent to cause said impact portion to impart a substantially instantaneous impact to the pendulum bob, and means for restoring the impulse member and the detent to a position such that said impact portion is maintained out of the path of said pendulum.

15. A combination as defined in claim 14, in

which a banking stop is provided to engage the impulse member at the instant of impact to cause the impact to occur at a desired intermediate point in the swing of the pendulum and to prevent prolongation of the contact between the impulse member and the bob.

16. In combination, a pendulum having a bob, a bell crank lever pivoted adjacent the path of said bob, one arm of said bell crank lever being adapted to impart instantaneous impacts to said bob, a detent member including a trigger engaging the other arm of said bell crank lever to maintain the impact arm out of the path of movement of the bob during movement of the pendulum in one direction, said trigger being movably mounted on said detent, a trigger pull on said pendulum, said trigger pull engaging said trigger when the pendulum is moving in said one direction without releasing said detent from said other arm but upon movement of said pendulum in the reverse direction, said trigger pull operating said trigger to release said detent from said other arm to impart an instantaneous impact to said pendulum bob by the impact arm of said bell crank lever, and means for restoring the bell crank lever to its original position with the impact arm out of the path of movement of the bob.

MARSTON LOVELL HAMLIN.

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Certificate of Correction

Patent No. 2,482,061 September 13, 1949

MARSTON LOVELL HAMLIN

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 3, line 18, for the words "and dial" read *the dial*; column 4, line 22, for "plane" read *plate*; line 36, for "plante" read *plate*; column 7, line 61, for "com" read *cam*; column 14, line 42, for "on near" read *or near*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of June, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents