Oct. 10, 1944. O. H. DICKE 2,359,973

ELECTRIC CLOCK SYSTEM

Filed Nov. 8, 1938 4 Sheets-Sheet 1

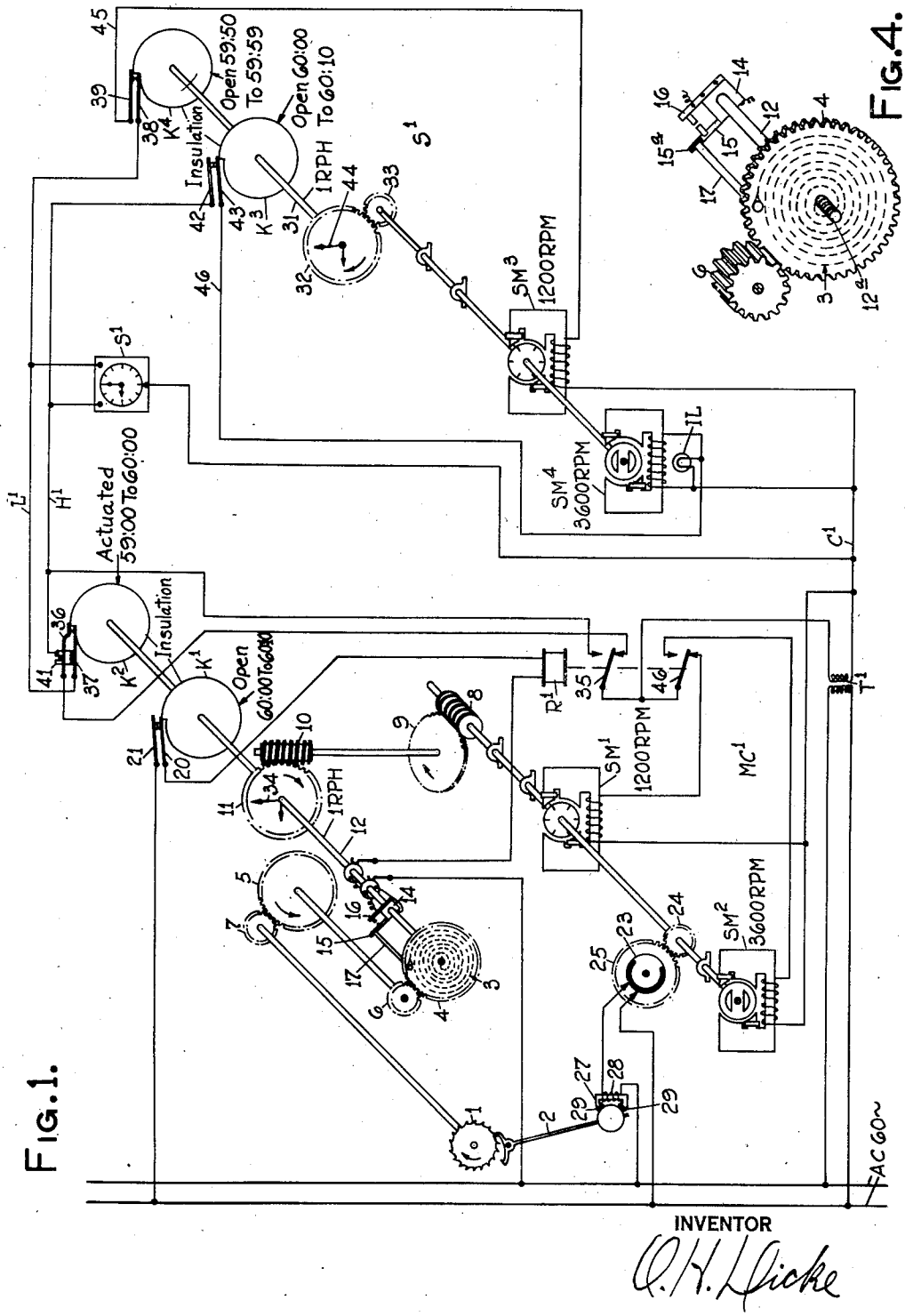


FIG. 1.

FIG. 4.

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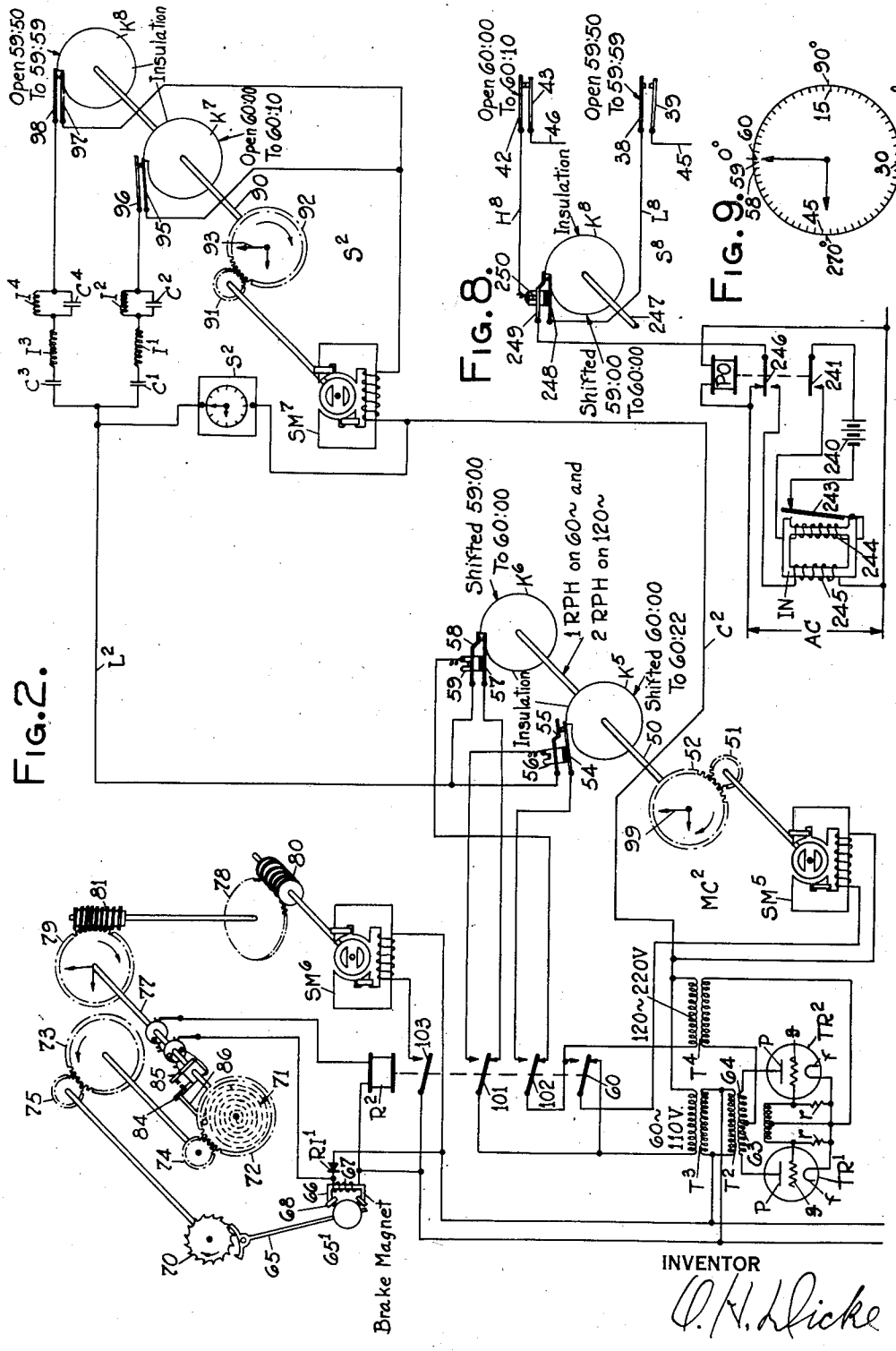


FIG. 2.

FIG. 8.

FIG. 9.

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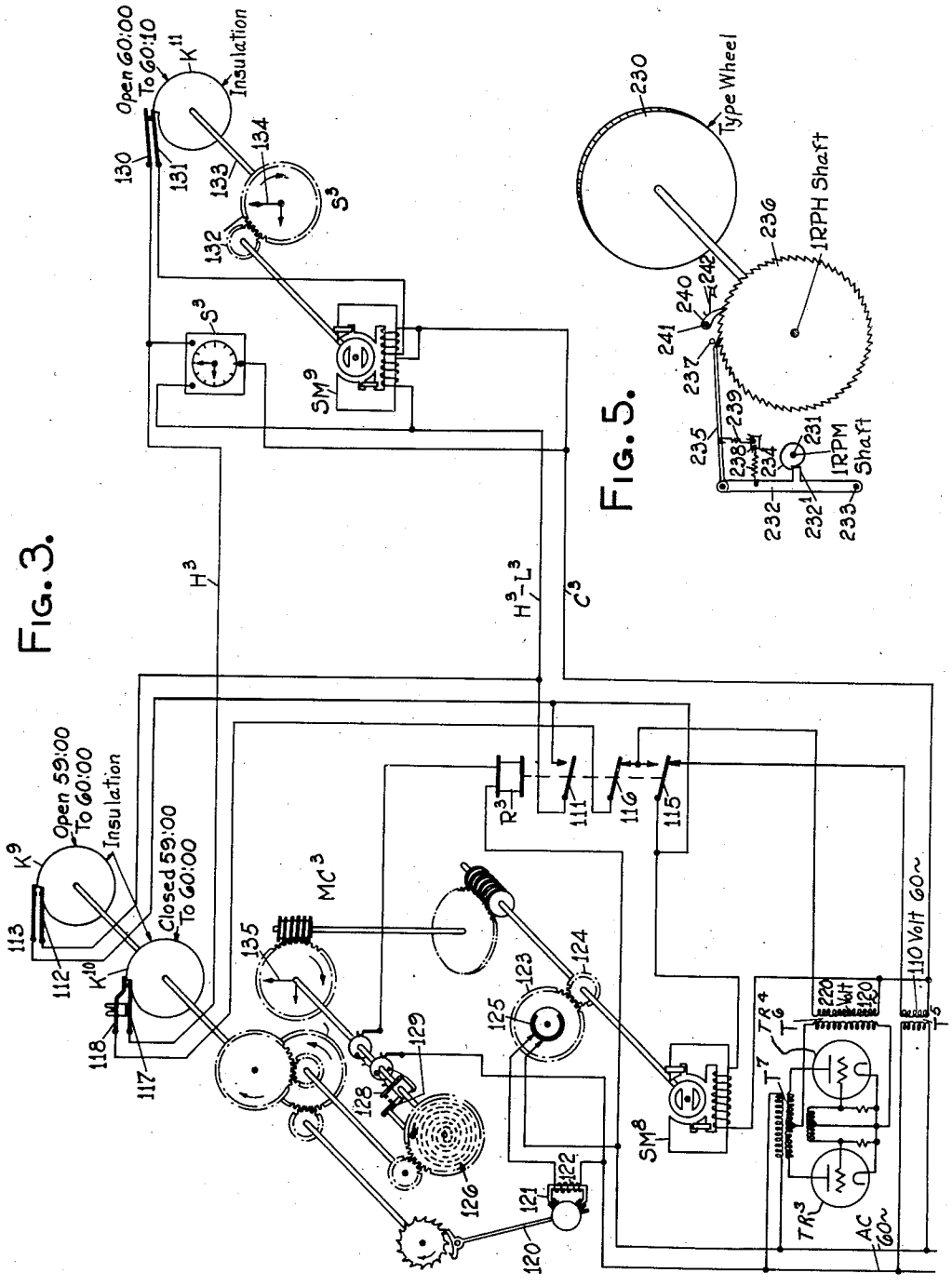


FIG. 3.

FIG. 5.

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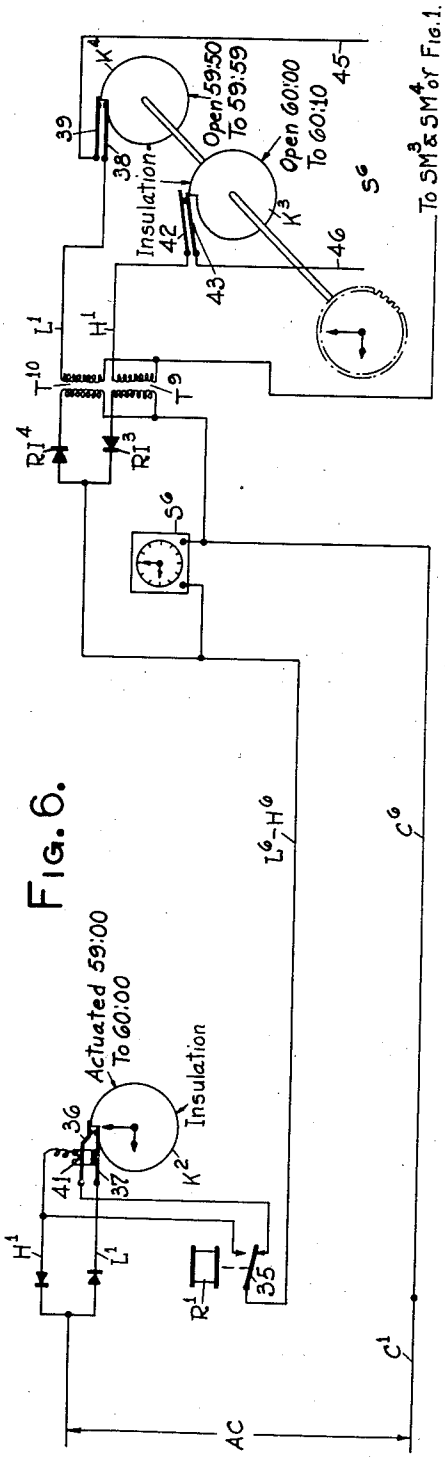


FIG. 6.

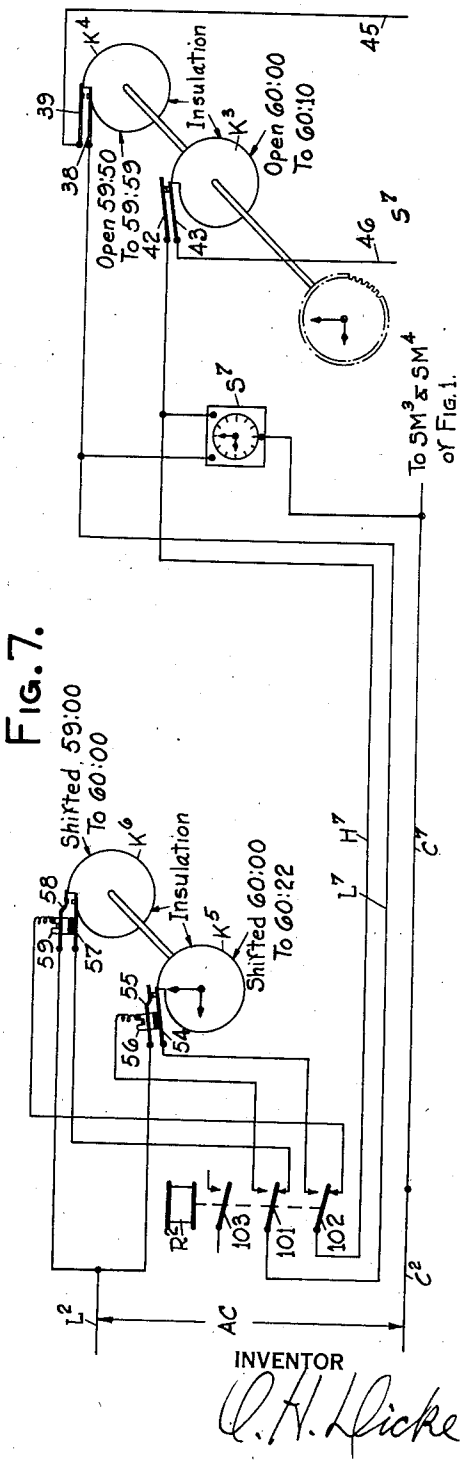


FIG. 7.

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Patented Oct. 10, 1944 2,359,973

UNITED STATES PATENT OFFICE

2,359,973

ELECTRIC CLOCK SYSTEM

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Application November 8, 1938, Serial No. 239,538

21 Claims. (Cl. 58—24)

The present invention relates to time control systems and more particularly to time clock systems driven by synchronous motors for punching or printing on a time card the time of arrival and departure of an employee to and from his place of employment, indicating time in railway stations, schools and office buildings, and the like.

In systems of the above type the secondary clocks may be corrected in the fifty-ninth minute, in that extreme accuracy in the last minute is not important.

In accordance with the present invention a slow secondary clock is advanced by a second or auxiliary synchronous motor which has a higher speed or is connected to the time shaft by a gear train having a higher gear ratio so as to rotate the time shaft at a higher speed; or is corrected by the same motor by operating it from higher frequency alternating current during the correcting period so as to make the time shaft run faster during correction of a slow clock. In accordance with the present invention a fast clock is corrected by stopping the secondary clock at a certain time indicating point and to again allow it to advance when the master clock reaches a corresponding time indicating point or several points.

One of the objects of the present invention resides in the employment of one or more synchronous alternating current motors in each secondary clock and to correct such secondary clock without the use of costly relays, electro-magnetic setting means or the like, synchronous motors being less costly to build than relays.

Another object of the present invention is to render the secondary clocks very quiet not only during the clock advancing period but also during the clock correcting period.

Another object of the present invention resides in the provision of novel master clocks in which one element of the master clock used for operating clock correcting contacts is always in substantial synchronism with the secondary clocks in spite of the fact that the secondary clocks are at rest during alternating current cessation, such current being derived from a commercial power system having its frequency regulated to correctly manifest passing of time.

Other objects of the present invention reside in the provision of master clocks in which joint action of escapement mechanisms and synchronous motors driven by alternating current of regulated frequency correctly manifest the passing of time and in which the master clock time shaft is advanced in accordance with current cycle passage during the presence of alternating current.

Other objects, purposes and characteristics and their advantages will appear from the following description when taken in connection with the drawings and from the drawings themselves in which:

Fig. 1 shows a three wire clock system in which the secondary clocks employ a double rotor double stator synchronous motor and in which the master clock comprises an alternating current dominated escapement clock;

Fig. 2 is a modified form of the invention in which an alternating current master clock is employed which master clock after each power failure is corrected by a normally stationary escapement clock and in which a single rotor secondary clock is automatically kept correct with the master clock over a single circuit through the medium of currents of different frequencies;

Fig. 3 is a modification which includes a master clock similar to Fig. 1 and employs currents of two different frequencies like in Fig. 2 but employs two circuits, one being used for normal advancing of the secondary clocks and for making a rough correction after each current cessation and the other being used for making a refined correction periodically;

Fig. 4 illustrates an enlargement of main spring gear, its extra long engaging pinion and the manner in which the main spring gear takes a lateral position on its shaft in accordance with the extent of winding of the main spring.

Fig. 5 illustrates how a continuously running minute shaft may intermittently drive an hour shaft so as to present a new type number every minute during the normal operation of the secondary clock.

Fig. 6 shows how Fig. 1 may be modified to eliminate one line wire.

Fig. 7 shows how the master clock of Fig. 2 may control the secondary clock of Fig. 1 by elimination of a second frequency current and by the addition of an extra line wire.

Fig. 8 shows how the secondary clocks of Fig. 1 may be controlled by a master clock including an auxiliary source of alternating current; and

Fig. 9 shows the clock dial of a further modification.

The inventions disclosed in this application are improvements over the inventions disclosed in my prior applications Ser. No. 365,584 filed May 23, 1929, now Patent No. 2,248,164 granted July 8, 1941; Ser. No. 441,109 filed April 2, 1930, now

Patent No. 2,331,267 granted Oct. 5, 1943; Ser. Nos. 729,079 and 729,080 filed June 5, 1934, now respectively patents, Nos. 2,248,165 and 2,185,334 granted respectively on July 8, 1941, and January 2, 1940; and the application of Robert H. Dicke Ser. No. 39,146 filed September 4, 1935, now Patent No. 2,151,317 granted March 21, 1939.

In accordance with the present invention it is proposed to employ or have available a commercial alternating current power distributing system delivering current of regulated frequency, that is, current having its average frequency regulated to correctly manifest time by cycle passage or summation. In each case the master clock is of a construction to be dominated so as to run in synchronism with alternating current cycle passage (see Figs. 1 and 3), or a construction including an electric master clock which is corrected in accordance with the duration of a current cessation after such current cessation (Figs. 2 and 7). The secondary clocks which they control may be used as tower clocks, as bell ringers or for any other program purpose.

It is also proposed to have secondary clocks of extremely simple construction. It is found that it is more economical to add an auxiliary motor than to add a relay, or an electrically operated clutch or gear shift. This is especially true if the added synchronous motor has its rotor mounted on the same shaft with the main motor so that no additional bearings are required as is the case in applicant's construction in Figs. 1, 6 and 7. It is also proposed to employ contacts to temporarily stop the secondary clock by opening the motor circuit to correct a fast secondary clock. In order to correct a slow clock it is proposed to employ a higher frequency alternating current, possibly a current of double frequency, see Figs. 2 and 3 for instance, or to apply current of the same frequency to a higher speed motor, such as a stator acting on a fewer poles rotor, see Figs. 1, 6 and 7, for instance. In each of Figs. 1, 2, 3, 6 and 7 the secondary clock is advanced after each alternating current cessation and is specially corrected at the end of each particular time interval such as an hour, and if the first mentioned correction carries through such even hour point on the secondary clock a special release is given to such secondary clock so that the feature which normally stops the clock when it has reached the even hour position cannot be effective. In the form of the invention shown in Fig. 3 similar corrections are made but the correction made after each power or current cessation is made through a circuit which does not include a contact broken by the secondary clock so that no such special release is necessary.

In the construction of Figs. 1, 6 and 7 the secondary clock is one in which two synchronous motors having common bearings is employed. As illustrated, one of these motors has a six pole rotor and has a synchronous speed of 1200 R. P. M. whereas the other has a two pole rotor and has a synchronous speed of 3600 R. P. M., and the construction is such that normally only the 1200 R. P. M. motor is energized.

Fig. 1 structure.—In this form of the invention an escapement master clock including the usual escape wheel 1 and pendulum 2 is employed. The escape wheel 1 is driven by the main spring 3 through the medium of gears 4 and 5 and pinions 6 and 7. This main spring is normally rewound at exactly the same rate that it runs down, the two worm reductions 8—9 and 10—11 being such that with synchronous motor SM^1 running at 1200 R. P. M. the shaft 12 is rotated at exactly 1 R. P. H. On this shaft is mounted an insulating block 14 having contacts 15 and 16 mounted thereon. These contacts are biased toward each other and if free are in actual contact with each other. When the main spring 3 is fully wound the contact 15 engages the pin 17 of insulating material, thus separating contacts 15—16 and opening the circuit for the relay R^1 unless the circuit for this relay R^1 was already open at contacts 20—21. Either of the synchronous motors SM^1 and SM^2 may also drive the rotary circuit closer 23 as through the medium of pinion 24 and gear 25. The pendulum 2 is dominated in any suitable manner as by electro-magnetic impulses as through the medium of electro-magnet 27—28. This electro-magnet 27—28 has the poles of the magnetic core 27 provided with rubber bumpers 29, for the purpose of silencing the impacting of this electro-magnet 27—28 by the pendulum. This dominating of a pendulum by electro-magnetic impulses is also disclosed in my prior application Ser. No. 365,584 above referred to. It should be noted that the circuit for electro-magnet 27—28 is closed at a rate three times as fast when the rotary circuit closure is driven by motor SM^2 than when driven by motor SM^1, this however does not detract from effective domination of the pendulum by the electro-magnetic impulses, because two of the three impulses occur when the pendulum is far away from the electro-magnet and furthermore because the effect of these two impulses is neutralized because one occurs when the pendulum is approaching and the other when the pendulum is receding. It may be pointed out that the pendulum is dominated in the following manner. When the pendulum is a little slow the electro-magnetic impulses accelerate it by first causing an increase in amplitude of the pendulum and by then allowing the pendulum to bounce off of the electro-magnet, so to speak. If the pendulum is fast it is held in contact with the electro-magnet temporarily at the end of each magnetic impulse, or is at least retarded when receding. It is this fact of domination of the escapement clock by a regulated frequency alternating current which current also drives the synchronous motor SM^1 that keeps the gear 4 and the shaft 12 in absolute synchronism and thereby keeps the contacts 15—16 just barely open, when they have once been opened, so long as no current cessation occurs. The winding shaft 12 has mounted thereon two contact operating disks K^1 and K^2. These disks have been mounted to rotate with shaft 12 rather than with gear 4 so that these disks remain at rest during a power cessation and rotate at a higher speed when high speed winding, through the medium of synchronous motor SM^2, takes place. Each secondary clock, only two of a plurality having been shown, comprises an hour shaft 31 driven at 1 R. P. H. by the synchronous motor SM^3 and driven at 3 R. P. H. by the synchronous motor SM^4 through the medium of a gear reduction train shown conventionally by the gear 32 and the pinion 33. This shaft is similarly provided with contact operating disks K^3 and K^4 which operate contacts 42—43 and 38—39 respectively.

Operation Fig. 1.—During normal operation of the clock system the pendulum 2 is in engagement with the energized electro-magnet 27—28 during each right hand stroke of the pendulum, the electro-magnet being energized intermit-

tently once for each period of the pendulum when this pendulum is adjusted to keep correct time. That is, if the pendulum makes a complete cycle in one second the contact **23** energizing the electro-magnet **27—28** closes once for each second when driven by the synchronous motor SM^1 and once each one-third second when driven by the synchronous motor SM^2. If the pendulum is a little slow it is accelerated by the electro-magnet and if a little fast it is retarded thereby. Also during normal operation of the system the secondary clock is operated between the zero minute and the fifty-nine minute position, as reflected by the clock hand **34** of the master clock, by the synchronous motor SM^3 through the following circuit: beginning at the source of alternating current comprising the secondary winding of transformer T^1, which has its primary winding fed from the commercial alternating current power system AC of regulated frequency, back contact **35** of relay R^1, normally closed contacts **36—37** operated by the disk K^2, low speed wire L^1, contacts **38—39**, operated by cam or disk K^4, wire **45**, winding of the synchronous motor SM^3 to the common return wire C^1, which is connected to the other terminal of said secondary winding. During the period between the fifty-nine minute and sixty minute position of the master clock alternating current voltage is applied to the following circuit: beginning at one terminal of the secondary winding of transformer T^1, back contact **35** of relay R^1, contacts **36—41** operated by cam K^2, high speed wire H^1, contacts **42—43**, wire **46**, and high speed motor SM^4, of the secondary clock S^1 through common return wire C^1 back to the other terminal of the secondary winding of transformer T^1. If the secondary clock was correct at the beginning of the fifty-ninth minute of the master clock it will be operated by current in the last traced circuit for twenty seconds at which time the secondary clock S^1 reaches the even hour position as reflected by the clock hand **44**, contacts **42—43** open. This is true because the secondary clock S^1 will run at three times normal speed during these twenty seconds. If the secondary clock was slow from zero to two minutes it will run correspondingly longer. For instance, if it was slow fifteen seconds it will run five seconds longer. It will be noted that contacts **38—39** are open between fifty-nine minutes fifty seconds position and the fifty-nine minute fifty-nine seconds position. From which it is apparent that contacts **38—39** will be reclosed by operation of synchronous motor SM^4 through the last traced circuit unless the secondary clock was slow more than two minutes. The secondary clock will however not be slow for more than two minutes because it is corrected to an extent depending on the duration of a power failure or current cessation immediately after such current cessation terminates.

For instance, let us assume that the secondary clock S^1 is exactly correct with the master clock MC^1 and that a fifteen minute current cessation starts at the fifteen minute position of the shaft **12** and clock hand **34** of the master clock MC^1 and the fifteen minute position of the shaft **31** and clock hand **44** of the secondary clock S^1. These shafts **12** and **31** will immediately stop, because these shafts were driven by synchronous motors SM^1 and SM^3, respectively. During the fifteen minute period of current cessation the pendulum **2** will not be dominated by the electro-magnet **27—28**, because there is no source of current AC present, and this is true even though contacts **23** happen to be closed during the time of current cessation. The pendulum will however very closely measure the duration of current cessation. After fifteen minutes, that is, when the gear **4** of the master clock MC^1 assumes the thirty minute position, as above assumed, alternating current is again available. Since however gear **4** has continued to operate, due to the main spring **3** driving the escape wheel **1**, the contacts **15—16** are now closed and the relay R^1 picks up immediately upon the return of alternating current. When this happens the contact **46** of relay R^1 disconnects the winding motor SM^1, operating at 1200 R. P. M., and instead connects the winding motor SM^2 operating at 3600 R. P. M. It is thus observed that the shaft **12** operates three times as fast as the gear **4** for which reason the contacts **15—16** would reopen fifteen-thirds of the minutes later, that is, would open five minutes later if the escapement stood still. Since the escapement portion of the master clock continues to operate the pin **17** continues to move away from the contact **15**. That is, the contact **15** gains with respect to the pin **17** at the rate of ten seconds for each five seconds of operation and therefore the contacts **15—16** will remain open seven and one-half minutes after the return of the alternating current power or at the thirty-seven and one-half minute position of the master clock. During this seven and one-half minute period immediately after the fifteen minute current cessation the shaft **12** was operated from the fifteen minute position to the thirty-seven and one-half minute position. This occurred because the synchronous motor M^2 operates at three times the speed of synchronous motor SM^1. During this seven and one-half minute period the contact **35** of relay R^1 assumed its raised position and therefore operated the synchronous motor SM^4 of the secondary clocks, only two such clocks S^1 having been shown, through the following circuit:—starting at one terminal of the secondary winding of transformer T^1, front contact **35** of relay R^1, high speed wire H^1, contacts **42—43** of secondary clocks, each having a synchronous motor SM^4 connected in series therewith, through the common return wire C^1, and back to the other terminal of the secondary winding of transformer T^1. During this seven and one-half minute interval the secondary clock will be operated at triple speed and will therefore assume the thirty-seven and one-half minute position when the current flow over the line wire H^1 is terminated. It is possible that there might be a slight error in this correction due to mechanical and electrical limitations, but this error will be removed at the end of the hour by the supplemental correcting function performed by the contacts **36—37—41** operated by the cam K^2 of the master clock, and any error that may be made by this supplemental correcting means will not be cumulative.

Let us now assume that the master clock MC^1 and the secondary clock S^1 assume the forty-five minute position and that a twenty minute current cessation takes place. As heretofore the cessation of alternating current stops the winding motor SM^1 as a result of which the cams or disks K^1 and K^2 are stopped. The escapement part of the master clock however continues to operate, thereby moving the pin **17** away from contact **15**, thus allowing this contact **15** to engage the contact **16**. With the cams K^1 and K^2 assuming the

forty-five minute position the contacts 20—21 and 36—37 are closed and contacts 36—41 are open. Upon the resumption of alternating current flow the relay R^1 is energized, thereby closing the energizing circuit for the synchronous winding motor SM^2 which winds the main spring at three times the speed of operation of gear 4. In other words, the winding motor is operating at a speed so that pin 17 catches up two seconds for every second of operation and the contact 15—16 will open in ten minutes. Also with relay R^1 energized the secondary winding of transformer T^1 is connected directly across wires H^1 and C^1, so that the motor SM^4 of the secondary clock is energized through contacts 42—43 and the secondary clocks S^1 operate at three times normal speed. These contacts 42—43 will however open after five minutes of operation of the synchronous motor SM^4 because this motor SM^4 operates at three times the speed of synchronous motor M^3 and the contacts 42—43 open at exactly the end of the hour as manifested by the secondary clock shaft and its clock hand 44. The secondary clock and the cams K^1 and K^2 of the master clock assume substantially the same position since both have been operated at three times normal speed from the forty-five minute position since alternating current power returned. In other words, at the time that the contacts 42—43 of the secondary clock S^1 opened the contacts 20—21 and 36—41 of the master clock MC^1 opened and contacts 36—37 of the master clock MC^1 closed. Opening of contacts 20—21 for ten seconds deenergizes the relay R^1 for ten seconds, so that curernt may for ten seconds flow from the secondary winding of transformer T^1 through back contact 35 of relay R^1, through contacts 36—37, through wire L^1, through contacts 38—39 of the secondary clock, which closed just before contacts 42—43 opened, through synchronous motor M^3 through common return wire C^1, back to the secondary winding of transformer T^1. The secondary clock will therefore run at normal speed for ten seconds, as will also the cams K^1 and K^2 of the master clock, because with relay R^1 deenergized these cams will be driven at normal speed by the synchronous winding motor SM^1. At the end of this ten second period the cam K^3 of the secondary clock S^1 will reclose its contacts 42—43 as will also the cam K^1 of master clock MC^1 reclose contacts 20—21 thereby reenergizing the relay R^1. This will re-establish the high speed circuit through front contact 35 of relay R^1 and contacts 42 and 43 of secondary clock S^1. When the master clock now assumes the fifteen minute ten second position (15:10) the winding contacts 15—16 will open, thereby deenergizing the relay R^1 and dropping its contacts 35 and 46. Dropping of contact 46 will substitute the synchronous winding motor SM^1 for synchronous winding motor SM^2, thereby causing winding of the master clock at the same rate as its main spring runs down, the pendulum of the master clock being dominated by the alternating current impulses applied by the contacts 23. Dropping of contact 35, with contacts 36—37 closed, causes the normal or low speed circuit for the secondary clock and including contacts 38—39 and low speed synchronous motor M^3 to be closed, so that the secondary clock again operates at normal speed.

By reason of the shifting from one motor to another at both the master clock MC^1 and the secondary clock S^1 there may be a slight error in the secondary clock, but this error should not exceed a few seconds and this error will be removed at the end of the hour by the refined correcting means including contacts 36, 37 and 41 of the master clock, the operation of which has been explained above. All of the contacts mentioned will of course be designed to give a little leeway to take care of inaccuracies in time.

Putting it briefly, the clock system shown in Fig. 1 is of a construction such that if a current cessation occurs which is of a duration so that it may be corrected through a circuit including front contact 35 of the relay R^1 before the end of the hour as manifested by the master clock, a correction of all secondary clocks will be made by operating all of these secondary clocks at three times normal speed for a time equal to half of the period of current cessation. If, however, the outage is such that this correction carries it through the even hour position then the secondary clocks are all temporarily operated through the low speed circuit and contacts 38—39 at normal speed for a ten second interval, this in order that the contacts 42—43 of all the secondary clocks may be reclosed, after which the correction by operating all secondary clocks at three times normal speed again continues until they have been corrected to within a few seconds. This ten second interval is determined by contacts 20—21 which deenergize and drop the relay R^1 for ten seconds. This correction may be in error to an extent of several seconds and because this error for successive corrections would be cumulative the applicant has provided a refined or supplemental correcting means which corrects in accordance with contacts controlled by the position assumed by the time shaft of the master clock, and therefore such error as there may be is not cumulative. This supplemental correcting means constitutes apparatus and contacts associated with the master clock for applying with the relay R^1 deenergized current to the high speed circuit H^1 during the last minute of the hour and which is capable of holding a secondary clock back, if it is fast, to an extent of 59 seconds and can advance a slow clock to the extent of one minute and fifty-nine seconds.

In the above description the time of opening and closing of the various cam operated contacts has been very precisely set forth. It should, however, be understood that the applicant does not limit himself to these precise values, these values having been, to a certain extent, chosen to facilitate description of the invention. Also, since the secondary clock during a correction following a power failure, that is a correction made by the relay R^1, the secondary clock S^1 may not be correct with respect to shaft 12 of the master clock MC^1 a certain allowance should be made. If under this condition the secondary clock is considerably slow the contacts 42—43 might not have reclosed during the deenergization of relay R^1. Therefore, if desired, the contacts 20—21 of the master clock may be constructed to open later and be open much longer, say for one-half minute or even longer. This would allow greater margin to take care of inaccuracies. In fact in one construction the contacts 20—21 may be open between the tenth and the thirtieth second of the hour. This would take care of any secondary clock that is from ten seconds slow to ten seconds fast with respect to the shaft 12. Similarly the other contacts may be varied in degree to allow margins for

mechanical inaccuracies. The indicating lamp IL indicates when the clock is being advanced.

Fig. 2 structure.—In the structure of Fig. 2 the functional results are substantially the same as those accomplished by the structure of Fig. 1. The structure, however, employs only two line wires and the master clock MC^2 is a synchronous motor operated clock with escapement clock governing means for causing the synchronous motor clock to run at double speed after each current cessation for a time equal to the time of such current cessation, as is also true of all secondary clocks, only two having for convenience been illustrated, the double speed being obtained by applying a double frequency. One of these secondary clocks has been shown structurally and the other has been shown conventionally but both have been designated S^2.

Referring to Fig. 2, the master clock MC^2 includes a synchronous motor SM^5 which when operated by normal frequency of preferably 60 cycles will drive the hour shaft **50** at 1 R. P. H. through a gear reduction including pinion **51** and gear **52**. This shaft **50** drives contact operating cams K^5 and K^6 operating and controlling contacts **54—55—56** and **57—58—59** respectively. This synchronous motor CM^5 is, during the presence of alternating current of regulated frequency derived from the source AC, supplied with either normal frequency alternating current through transformer T^3 or is operated by alternating current of double frequency derived from transformer T^4 as determined by the condition of energization of relay R^2 through its contact **60**. The transformer T^4 is supplied with pulsating current of 120 cycle frequency through the medium of a frequency doubler, comprising thyratrons TR^1 and TR^2. These thyratrons are really gas filled grid initiated or grid controlled rectifiers, each having a grid *g*, a filament *f* and a plate *p*. The grids are each provided with a grid leak *r* and are activated from the secondary winding **63** of the transformers T^2. The filaments *f* are also energized from a secondary winding (not shown) of this same transformer. The various constants are preferably so chosen that rectification of substantially the second half of each half, namely, the second half of the positive and the second half of the negative wave of each cycle of current is rectified. This is done in order that the rectified waves, derived from the plate circuits including secondary winding **64** of transformer T^2, and which currents flow in the same direction in the primary winding of the transformer T^4 may be separated by a time period substantially equal to their duration, so that alternating current of 120 cycle and of substantial quantity will be delivered at the terminals of the secondary winding of this transformer T^4. In order to get the rectifying action for each wave of the alternating current to be started by its thyratron at or near the middle of the current wave it may be necessary to employ suitable phase shifting apparatus. Such phase shifting apparatus is employed for properly phasing the grid circuit for tube TR^1 in the prior application of Hoppe Ser. No. 120,421 filed January 13, 1937, now Patent No. 2,131,735, dated October 4, 1938, to which reference may be had. This phase shifting apparatus comprises an inductance PL^2 and a resistance PR^2 of the prior application connected in series across the secondary winding of a transformer, with the potential difference between an intermediate point of said secondary winding and the junction between said inductance PL^2 and said resistance PR^2 as the phase displaced electro-motive force to activate the grid of the thyratron.

This master clock MC^2 includes an escapement clock mechanism and a synchronous motor clock mechanism in combination. This escapement clock is shown conventionally as a pendulum clock, comprising a pendulum **65**, having a soft iron magnetic bob 65^1, normally held at rest by the direct current electro-magnet **66—67** energized by direct current derived from the same source of regulated frequency current through the medium of rectifier RI^1. This electro-magnet has each leg surrounded by a ring or slug of copper or other suitable conducting material in order to make the direct current magnet slow releasing. This electro-magnet is made slow releasing in order that the escapement clock may measure a slightly smaller time than the actual time of a current cessation and in so doing will cause the relay R^2 to be energized a correspondingly shorter time in order that the synchronous motor SM^5 will be energized by double frequency alternating current a slightly shorter period than the actual duration of the current cessation. This is done to remove the error that would otherwise creep in due to the coasting of the motor SM^5 during the current cessation. It has been found that if a small synchronous motor of the type contemplated is energized for one second it will rotate an extent equal to one and one-half seconds. That is, if it is two pole it will rotate 90 revolutions instead of 60. This pendulum controls an escape wheel **70** which is driven by a main spring **71** through the medium of gears **72** and **73** and pinions **74** and **75**.

This main spring **71** is electrically wound through the medium of shaft **77**, worm-wheels **78** and **79** and worms **80** and **81** by the synchronous winding motor SM^6. This worm reduction gearing including worm-wheels **78** and **79** and worms **80** and **81** has a rotation ratio such that when the spring winding motor SM^6 operates at synchronous speed from the alternating current regulated source it will turn the shaft **77** exactly one revolution in one hour. In other words, if a current cessation has occurred, upon return of power the contacts **84—85**, which are normally held open by the pin **86** being engaged by the contact **84** and holding it away from the contact **85**, and which are closed by any power cessation of less than one hour, will be opened when the power has been restored for a time equal to the extent of the duration of such cessation minus about a half second. This half second difference is due to the fact that the escapement ran a half second less time than the extent of the power cessation, and this was by reason of the slow acting release of the brake magnet due to its slug **68**. The rectifier RI^1 is also included in series in the energizing circuit for the relay R^2 to render the relay quiet.

Referring now to the secondary clock, each secondary clock, only two having been shown both designated S^2, includes a minute shaft **90** (rotating one revolution per hour) driven by a synchronous motor SM^7 through reduction gearing including pinion **91** and gear **92**. The shaft **90** drives two cams K^7 and K^8 which control snap acting contacts **95—96** and **97—98**, respectively. The contacts **97—98** snap open at 59:50 (meaning fifty-nine minutes and fifty seconds) and snap closed at 59:59, whereas the

contacts 95—96 snap open at the end of the sixtieth minute and snap closed at the end of the tenth second of the hour. The contacts 95—96 have included in series therewith two tuned units C^1—I^1 and C^2—I^2. The condenser C^1 and inductance I^1 are included in series and tuned to current resonance at 120 cycles and the condenser C^2 and inductance I^2 are connected in multiple to resonate at 60 cycle potential to greatly restrict the flow of 60 cycle current, thus allowing the free flow of current of 120 cycles. Similarly, condenser C^3 and inductance I^3 are included in series to resonate for current resonance at 60 cycle at permit the free flow of 60 cycle and restrict the flow of 120 cycle current, whereas the condenser C^4 and inductance I^4 are connected in multiple and have values of capacity and inductance to cause them to resonate at 120 cycle potential resonance to greatly restrict the flow of 120 cycle current while not materially restricting the flow of 60 cycle alternating current.

Operation Fig. 2.—Under normal operating conditions 60 cycle or low frequency current is applied to the line wire L^2 between the zero position and the 59:00 minute position of the master clock as indicated by clock hand 99 through the following circuit: starting at secondary of transformer T^3, back contact 101 of relay R^2, contacts 57—58 controlled by cam K^6, wire L^2, condenser C^3, inductance I^3, condenser C^4 and inductance I^4 in multiple, contacts 97—98 operated by cam K^8, synchronous motor SM^7, common return wire C^2, back to the secondary winding of transformer T^3. Under this normal condition the secondary clock S^2 operates at normal speed and the escapement portion of the master clock is of course at rest, there being normally no power failure. During the entire sixtieth minute of the master clock (see hand 99), when the contacts 57, 58 and 59 are in their actuated position as shown in the drawings the contacts 58—59 are closed and the contacts 57—58 are open. Under this condition current of high frequency, namely, 120 cycle, in the particular system illustrated, is applied to the synchronous motors of the secondary clocks, only one motor having been shown, through the line circuit including back contact 102 of relay R^2, contacts 59—58, line wire L^2, condenser C^1 and inductance I^1 in series and condenser C^2 and inductance I^2 in multiple, and including the contacts 95—96 controlled by the cam K^7. The synchronous motor SM^7, will, of course, operate at double normal speed when energized by current of double frequency. At the 59:30 minute position of the master clock the contacts 95—96 of the secondary clock will open, namely, when the secondary clock assumes the 60:00 minute position (see hand 93), it having operated at double speed during this time. The secondary clock will then stop, and at the 60:00 minute position as manifested by the clock hand 99 of the master clock the contact 58 of the master clock will shift from the contact 59 to the contact 57, thereby reapplying current of 60 cycle frequency to the secondary clock. It is desired to point out that 60 cycle current can only reach contacts 97—98 and likewise current of 120 cycle frequency can only reach contacts 95—96 of the secondary clock. This is the case because unit C^1—I^1 is tuned to 120 cycle and permits the free flow of 120 cycle current but restricts the flow of 60 cycle current, whereas condenser C^2 and inductance I^2 are tuned to 60 cycle so as to restrict the flow of 60 cycle current but they allow comparative free flow of 120 cycle current. On the other hand, unit C^3—I^3 is tuned to 60 cycle and unit I^4—C^4 is tuned to 120 cycle for similar purposes, that is, to allow the free flow of 60 cycle current but to restrict the flow of 120 cycle current.

Let us now assume that at the 30 minute position of the master clock MC^2 and the secondary clock S^2 a current cessation takes place. This cessation of current deenergizes the brake magnet 66—67 causing it to release the pendulum 65 after about one half second delay. Since the synchronous motor SM^5 will coast for an equal period of time the escapement clock will still measure the amount of time the electric synchronous motor part of the master clock will have lost upon return of the alternating current power. This operation of the escapement portion of the master clock causes the main spring 71 to run partly down, causing the pin 86 to disengage from the contact spring 84 thereby causing the contacts 84—85 to close. The relay R^2 remains deenergized until power returns which we will assume to be at the forty minute position of the master clock. This return of power will cause locking of the pendulum 65 against the brake magnet 66—67 and will cause picking up of the relay R^2. Picking up of the contact 60 of the relay R^2 will cause the synchronous motor part of the master clock MC^2 to run at double speed, because the synchronous motor SM^5 is energized by double frequency current. Also lifting of the contact 102 of relay R^2 applies current through the front contact 102, the closed contact 54—55, line wire L^2, the tuned unit C^1—I^1, the untuned unit C^2—I^2 for 120 cycle current, the contacts 95—96 through the winding of synchronous motor SM^7, back to the 120 cycle source. This will of course cause the secondary clock S^2 to advance at double speed. Both of the shafts 50 and 90 will therefore run at double speed and this will continue for a time equal to the duration of the current cessation. This is true for at the expiration of such a period of time the contacts 84—85 of the master clock will be opened, resulting in deenergization of the relay R^2, stopping of the winding motor SM^6 and the return to normal speed of the synchronous motors SM^5 and SM^7. The shaft 50 will therefore reflect exactly correct time and the shaft 90 will reflect substantially correct time.

As the shafts 50 and 90 continue to run in substantially synchronous rotation the contacts 57—58 open and the contacts 58—59 close, this occurring near the end of the hour of the secondary clock and at the beginning of the sixtieth minute of the master clock MC^2. This will cause 120 cycle frequency instead of 60 cycle frequency current to be applied to the secondary clock S^2. This 120 cycle current can however, by reason of the tuned units, flow only through contacts 95—96, and these contacts 95—96 open at exactly the end of the hour as reflected by the hand 93 of the secondary clock. If the secondary clock was as much as 59 seconds fast it will be held at the end-of-hour position and if it was as much as a minute slow it will reach the end-of-hour position by the time the master clock reaches the end-of-hour position. The secondary clock will thus receive a refined correction, which cannot have a cumulative error, and this takes place at the end of each hour.

Let us now assume that a power cessation occurs that either continues through the end-of-hour position or in which the correction carries

through the end-of-hour position of the master clock. Let us assume that a power cessation of 20 minutes starts at the 50 minute position of the master clock.

As heretofore pointed out all the electrical apparatus stops during a current cessation and the escapement portion of the master clock MC^2 operates during such current cessation. At the end of the twenty minute cessation the pin **86** will have moved away from the spring contact **84** an arc of substantially one-third of a revolution.

Upon return of power the pendulum **65** is braked, the winding synchronous motor SM^6 is started and the synchronous motors SM^5 and SM^7 are started and run at double speed. Since shafts **50** and **90** are both driven at twice normal speed the contacts **57—58** open after power has been on again for four and one-half minutes, that is, when shaft **50** assumes the 59 minute position, but since high frequency current (120 cycles) flows directly to the line wire L^2 from the front contact **102** through contacts **54—55**, the opening of contacts **57—58** is of no importance particularly since back contact **101** is open. Also, the closing of contacts **58—59** is of no importance since back contact **102** of the relay R^2 is open. At the 59:50 minute position of the secondary clock S^2 and the shaft **90** the contacts **97—98** open but this is of no immediate importance since no current has been flowing therethrough. These contacts **97—98** reclose at the 59:59 minute position of shaft **90**. At the 60:00 minute position of the master clock and the secondary clocks and shafts **50** and **90** the contacts **54—55** open and contacts **55—56** close (see master clock) and the contacts **95—96** of the secondary clock S^2 open. The opening of either contacts **54—55** or contacts **95—96** would stop the synchronous motor SM^7 of the secondary clock, but the closing of contacts **55—56** of the master clock cause the secondary clock to continue to operate but at normal instead of double speed, through a circuit readily traced and including front contact **101** of relay R^2, contacts **56—55** at the master clock and contacts **97—98** of the secondary clock. This circuit will only be maintained closed for eleven seconds at which time it will be broken at contacts **55—56**, and was established to reclose contacts **95—96** of the secondary clock, so that the high speed circuit including these contacts **95—96** as well as contacts **54—55** of the master clock may be re-established. During the closure of the low speed circuit including contacts **55—56** of the master clock the shaft **50** was running double speed while the shaft **90** was running at only normal speed, so that the secondary clock may have lost approximately ten seconds. This will, however, be corrected at the end of the next hour for reasons heretofore explained. Upon reclosing of contacts **54—55** of the master clock contacts **95—96** of the secondary clock having also been reclosed the secondary clock resumes its double speed, through a circuit including these contacts. At approximately the ten minute position of the master clock the synchronous winding motor SM^6 will have caused the main spring **71** to have been fully wound and will cause the contact spring **84** to engage the pin **86** thereby opening the contacts **84—85** and deenergize relay R^2. Deenergization of relay R^2 causes the contact **60** to drop to apply 60 cycle current to the electric synchronous motor portion of the master clock, that is, to the synchronous motor SM^5 instead of 120 cycles. This causes the shaft **50** to rotate at normal speed instead of double speed. This shaft **50** now correctly manifests time. Dropping of the relay R^2 opens its contact **103** and stops the winding motor SM^6. Also dropping of the relay R^2 removes 220 volt 120 cycle current from the secondary clock by the opening of front contact **102** and causes the application of 110 volt 60 cycle current thereto by the closing of back contact **101**. The secondary clock will now operate at normal speed and will indicate time correctly except that it is now approximately eleven seconds slow. This small error will however be corrected at the end of the hour for reasons and in a manner as already explained. Although as pointed out above the contact **54—55—56** controlled by cam K^5 are shown to assume an abnormal position between the 60 minute and the 60:22 minute position of the master clock these contacts may be constructed to actually assume the abnormal position for a whole minute after the 60 minute position. This latter construction would allow for greater discrepancy between the secondary and the master clock. It would however cause the secondary clock to be about one-half minute slow which error would be corrected at the end of the next hour.

Fig. 3 structure.—The system shown in Fig. 3 employs a master clock similar to that illustrated in Fig. 1, in that the escapement clock is one of the continuously operated type, which clock is synchronized with the frequency of the alternating current which is regulated to correctly manifest the passing of time. The system of Fig. 3 itself is similar to that illustrated in Fig. 2 in that double frequency current is employed to cause a secondary clock to catch up, so to speak. The frequency doubler including thyratron tubes TR^3 and TR^4 is identical to the one shown in Fig. 2 for which reason it will not be described. This system shown in Fig. 3 is similar to those shown in Figs. 1, 2, 6 and 7, and is one where the secondary clocks are corrected immediately upon return of power after a power failure or current cessation and wherein a supplemental and more accurate correction of secondary clocks is made periodically, as for instance, at the end of each hour.

There is, however, one important difference between the systems of Figs. 1 and 2 and Fig. 3, and that is that the system in Fig. 3 will only correct a fast secondary clock providing it is not more than one minute fast and that is accomplished by removing the low frequency current at the end of the fifty-ninth minute and not reapplying it until the end of the sixtieth minute (end of hour) and by applying double frequency to the H^3 circuit during the last minute of the hour. This construction does not require a contact operated by the secondary clock in the high low or H^3—L^3 circuit, and permits a correction to be made after a current cessation wholly by the relay R^3, which relay is picked up at the termination of the current cessation and not dropped until after having been energized for a time equal to such duration when it is dropped. This relay R^3 by the closing of front contact **111** shunts the contacts **112—113** controlled by the cam or disk K^9 so that the contact **115** of relay R^3 can apply either 60 cycle 110 volt current to the wire H^3—L^3 or can apply 120 cycle 220 volt current to this wire H^3—L^3. The back contact **116** of relay R^3 is employed to prevent current of high frequency (120 cycle) from flowing to contacts **117—118** while relay R^3 is in its energized position. This contact **116** is employed

to prevent both windings on the synchronous motors of the secondary clocks S^3 being energized at the same time by alternating current of double frequency, because this might cause over saturation of the synchronous motor and possibly inaccuracy in its speed of operation.

Referring to Fig. 3, like in Fig. 1 the pendulum 120 is synchronized by an electro-magnet 121—122 which is provided with rubber shoes, so to speak, to dampen the noise due to the pendulum striking the electro-magnet and also to afford something resilient for the pendulum to bounce away from. It may be pointed out that the pendulum 120 if slow is accelerated by bouncing away from the rubber and if fast is retarded by being held toward the electro-magnet during each magnetic pulse until the magnet is deenergized. When the pendulum is slow it has not reached the rubber bumper when the magnetic impulse is terminated, but the pendulum is close enough to have been accelerated by such impulse as a result of which the fast approaching pendulum strikes the rubber bumper and then bounces away from it. The electro-magnet is preferably energized for a moment at the end of each pendulum swing when the winding motor SM^8 is operated from 60 cycle current and energized four times for each pendulum cycle when the winding motor is operating double speed due to being energized by 120 cycle 220 volt alternating current. Like in the Fig. 1 construction intermittent energization of the electro-magnet 121—122 is accomplished through the medium of commutator 125 driven through the medium of gear 123 and pinion 124 by the synchronous winding motor SSM^8. This doubling of the electro-magnetic impulses as compared with the number of engagements of the pendulum 120 with the electro-magnet 121—122 when the synchronous motor SM^8 is operating at normal speed is resorted to to effect less domination of the electro-magnet over the pendulum when the pendulum is out of step or synchronism with the electro-magnetic impulses. It has been experienced that if only one magnetic pull per pendulum cycle is employed that there is a tendency for the electro-magnet to stop the pendulum when the magnetic pulses and the pendulum swings are in phase opposition. This detrimental effect is entirely eliminated by the employment of double frequency magnetic pulses as compared with the pendulum frequency. There is also another difference between the master clock of Fig. 3 from that shown in Fig. 1 and that is that the correcting cams K^9 and K^{10} are driven directly by the escapement mechanism and therefore operate during the duration of current cessation. The advantage of having the correcting cams a direct part of the master escapement is that they will be a little more accurate than cams located on the winding shaft as is true in Fig. 1. The inaccuracy in the Fig. 1 construction can however be kept as low as one second and since this inaccuracy is not cumulative it may be disregarded.

Operation Fig. 3.—Under normal conditions, that is betwen the zero position and the fifty-nine minute position of the master clock MC^3 and when no current cessation has taken place the synchronous winding motor SM^8 winds the escapement clock main spring 126 at exactly the rate that the escapement portion of the clock unwinds the main spring 126, so that the contacts 128—129 remain just barely open. Under this normal condition the secondary clock S^3 is connected to the secondary winding of the 60 cycle transformer T^5 through the following circuit: beginning at the upper terminal of this secondary winding, back contact 115 of the relay R^3, contacts 112—113 operated by cam K^9, and closed only during the first fifty-nine minutes of the hour as manifested by the master clock, line wire H^3—L^3, winding of the synchronous motor SM^9, operating one of the secondary clocks S^3, through gear reduction 132 in a manner such that shaft 133 and minute hand 134 rotate at 1 R. P. H. when the synchronous motor is operating at synchronous speed with regulated 60 cycle current applied thereto, through the common return wire C^3 back to the other terminal of this secondary winding.

When the master clock reaches the fifty-nine minute position the contacts 112—113 operated by the cam K^9 open and the contacts 117—118 operated by the cam K^{10} close. This operation of these contacts removes low frequency current (60 cycle) from the high-low wire H^3—L^3 and applies high frequency current (120 cycles) to the high wire H^3. This high frequency circuit starts at the upper terminal of the secondary of the transformer T^6, back contact 116 of the relay R^3, contacts 117—118 operated by the cam K^{10} and closed only during the sixtieth minute of the hour as manifested by the master clock, high wire H^3, contacts 130—131 controlled by the cam K^{11} of the secondary clock, through the first winding of the synchronous motor SM^9, through the common return wire C^3 back to the transformer T^6. If the secondary clock S^3 was fast to an extent less than one minute it will be held at the sixty minute position and if it was slow less than one minute it will be advanced during the sixtieth minute of the master clock to the sixty minute position at which point the circuit is opened at contacts 130—131 by the secondary clock S^3. At the end of the sixtieth minute of the master clock as manifested by the hand 135 and the positions assumed by the cams K^9 and K^{10} the contacts 117—118 will open and the contacts 112—113 will reclose as a result of which 120 cycle current will be cut off the wire H^3 extending to secondary clocks S^3 and 60 cycle current will be reapplied to the high-low wire H^3—L^3.

Let us now assume that a current cessation occurs at the fifty minute position of the master clock MC^3 and the secondary clock S^3 and that this current cessation continues until the fifty-eight minute position is assumed by the master clock. The master clock will continue to run in spite of the fact that the winding motor stops the main spring having at least an hour and possibly as much as twenty-four hours reserve of energy. Upon return of alternating current at the fifty-eight minute position of the master clock MC^3 the contacts 128—129 being closed the relay R^3 will be energized. Opening of the back contact 116 of this relay merely opens the line circuit at a second point it already being open at contacts 117—118. The lifting of contact 115 applies double frequency alternating current to the winding motor SM^8, thereby causing this synchronous motor to operate at double normal speed, which will cause it to catch up after an interval of running equal to the time of the current cessation that is at the six minute position of the master clock. The lifting of this contact 115 also applies 120 cycle current to the synchronous motor SM^9 of the secondary clocks S^3 through the high frequency circuit including the high-low wire H^3—L^3. This high frequency cir-

cuit may be traced as follows: starting at the upper terminal of the secondary winding of transformer T^6, front contact **115** of relay R^3, front contact **111** of the relay R^3, wire H^3—L^3, the other winding of the synchronous motor SM^9, common return wire C^3 to the bottom terminal of said secondary winding. During the time of correction, that is, between the fifty-eight minute and the six minute position of the master clock MC^3 the contacts **112**—**113** and **117**—**118** will be operated, but this will not have any affect on the secondary clocks because the circuit leading to contacts **117**—**118** is open at back contact **116** of relay R^3 and the contacts **112**—**113** are shunted by the front contact **111** of the relay R^3. It is thus seen that power failure error of the secondary clocks may be corrected even though such correction extends through the even hour position of the master clock, and also independent of cam operated contacts for which reason the cams K^9 and K^{10} may be located directly on a continuously rotating master clock shaft as illustrated in Fig. 3. That is, in the structure of Fig. 3 the secondary clock correction that is made immediately after a current cessation is made wholly by the relay R^3 controlled through the medium of re-winding contact **128**—**129**, and is made through a circuit which does not include secondary clock operated contacts.

Fig. 6 structure.—The modification shown is a system which functions the same as that shown in Fig. 1, but instead of showing two control line wires energized at different times by current of one character Fig. 6 employs a single control line energized at different times by different character currents. It will be noted that in Fig. 1 the contacts **35**, **36**, **37** and **41** apply alternating current to the control lines L^1—H^1, whereas in Fig. 6 these same contacts are connected in reverse order and apply either pulsating current of one polarity or pulsating current of another polarity to the single control line L^6—H^6.

The secondary clock of Fig. 6 is the same as that shown in Fig. 1 except that two rectifiers RI^3 and RI^4 and transformers T^9 and T^{10} have been added. The rectifier RI^3 in combination with transformer T^9 serves to convert pulsating current of negative polarity to alternating current and apply it to contacts **42**—**43** from whence it may at times reach the high speed synchronous motor SM^4 through wire **46**; whereas the rectifier RI^4 in combination with transformer T^{10} will convert pulsating current of positive polarity into alternating current and apply it to the contacts **38**—**39** which contacts when closed allow this alternating current to reach the low speed motor SM^3 (see Fig. 1) through wire **45**.

Operation Fig. 6.—The system of Fig. 6 operates the same and performs the same function in a different way as Fig. 1 for which reason it is believed unnecessary to discuss this operation.

Fig. 7 structure.—The secondary clocks of Fig. 7 are identical to the secondary clocks of Fig. 1 and the master clock of Fig. 7 is identical to that of Fig. 2 except that the contacts operated by the cams K^5 and K^6 and the relay R^2 contacts are connected in reverse order between a source of current and the control wires, and the electric clock portion of the master clock is driven by one or the other of two synchronous motors (not shown) as is the rewind shaft of the master clock of Fig. 1 instead of being driven at two different speeds by applying alternating currents of two different frequencies to a single synchronous motor as indicated in Fig. 2. In Fig. 2 the line wire L^2 is switched from one source of current (60 cycle) to another source of current (120 cycle) as conditions require, whereas in Fig. 7 one source of current (60 cycle) is switched from one control line (L^7) to another control line (H^7) as conditions require. Referring to Fig. 2 it should be noted that contacts **55** and **58** are connected to the control line wire L^2, whereas in Fig. 7 these same contacts are connected directly to the source of alternating current. Also in Fig. 2 the contact **101** of relay R^2 is connected to the low frequency source (60 cycle) whereas in Fig. 7 this contact **101** is connected to the low speed wire L^7; and that the contact **102** of relay R^2 of Fig. 2 is connected to the high frequency source (120 cycle) whereas this contact **102** in Fig. 7 is connected to the high speed line H^7. It is thus apparent that the master clock of Fig. 2 as used in Fig. 7 applies alternating current to the low speed line wire for those time periods that the master clock of Fig. 2 applies low frequency alternating current to the only control line wire, and that the master clock used in Fig. 7 applies alternating current to the high speed line wire during those time periods that the master clock of Fig. 2 applies high frequency current to the only control line wire.

Operation of Fig. 7.—Since the system illustrated conventionally in Fig. 7 performs the same functions as does the system of Fig. 2 and employs different apparatus only for performing such function it is believed unnecessary to describe its operation.

Fig. 4 construction and operation.—Referring to Fig. 4 the rewind organization of each of Figs, 1, 2, 3, 6 and 7 is preferably constructed as illustrated in this figure. In the construction illustrated in Fig. 4 the main gear **4** has a threaded center opening provided with a left-hand thread. This gear **4** is then screwed onto the left-hand thread **12a** on the shaft **12**. The construction is such that with the main spring fully wound the wheel **4** is screwed onto this shaft **12** a longitudinal distance such that the pin **17** upon further winding by rotation of shaft **12** will cause the insulated portion **15a** of contact spring **15** to engage this pin **17**. The inner end of main spring **3** is of course fastened to the shaft **12** at a point so as not to interfere with the threaded engagement between shaft **12** and gear **4**. By this construction a current cessation of as much as five hours may be corrected, because rotation of the pin **17** about the shaft **12** in a clockwise direction is freely permitted for a plurality of revolutions. After cessation of current has ceased the rewind motor will operate the shaft in a clockwise direction for the same number of revolutions, that is, until the insulated portion **15a** of the contact **15** again engages the pin **17**.

Fig. 5 construction and operation.—In Fig. 5 has been illustrated how a continuously operated one revolution per minute shaft of any one of the secondary clocks of Figs. 1, 2, 3, 6 and 7 may be converted into an intermittently operated one revolution per hour shaft. Such an intermittently driven hour shaft (1 R. P. H.) is desirable where the secondary clock is employed to record or register time in suitable intervals preferably minute intervals. In the construction illustrated it is proposed to register minute intervals by the type wheel **230**. In the construction shown the shaft **231** is operated by the synchronous motors of one of the secondary clocks shown in Figs. 1, 2, 3, 6 or 7 in a clockwise direc-

tion and at a speed of one revolution per minute. The arm **232** pivoted at **233** and having a lug **232**[1] has its lug engage the cam **234** keyed or otherwise fastened to the shaft **231**. This arm **232** has pivoted thereto a pawl **235** so shaped that it will engage the teeth of the ratchet wheel **236** and when it has operated this ratchet wheel **236** an arc equal to one ratchet tooth this pawl will bind under the pin **237**, so as to avoid overthrow. That is, to avoid the ratchet wheel **236** being turned more than one tooth one-sixtieth of a revolution for each rotation of the shaft **231**. The arm **232** is biased to the right by a spring **238** and the pawl **235** is biased down by the spring **239**. The holding pawl **240** is pivoted to a stationary support by a pivot **241** and is urged in engagement with the ratchet wheel **236** by a spring **242**. From the construction illustrated in Fig. 5 it is readily seen that during the major part of each revolution of the shaft **231** the arm **232** is gradually moved toward the left and that at the end of each minute, or other suitable interval, the lug **232**[1] slips off of the cam **234** thereby causing the ratchet wheel **236** to be advanced in a clockwise direction six degrees, or an amount equal to one minute. This wheel **236** operates the type wheel **230**, and for each operation of the pawl **235** advances this type wheel to the next minute number. This type wheel may through suitable means operate other type wheels intermittently, once for each type character thereon, to indicate the hour of the day, the day of the week or month, and the like.

Summary

The systems of secondary clock operation and correction illustrated in Figs. 1, 2, 3, 6 and 7 show how secondary clocks of very simple and economic construction may be corrected in accordance with a master clock and how this master clock may be controlled in accordance with cycle passage of an alternating current derived from a commercial power system which has its frequency regulated to correctly manifest the passing of time. Not only does each of these systems correct the secondary clocks after each current cessation but supplemental corrections are made after equal time intervals thereafter by apparatus functioning in a manner so that if errors occur these errors are not cumulative. To clarify this statement, if a correction is made by speeding up a secondary clock in accordance with the duration of a current cessation each of a plurality of such errors that such apparatus might make would be added together. If on the other hand a secondary clock is speeded up until it reaches a particular time indication as determined by stop means within the secondary clock any error that such apparatus might make would be reflected in the same way as the several hands of a clock are sometimes not in agreement, i. e. these errors would be present but would not be reoccurring additively.

It should be understood that even though in the system shown in Figs. 2 and 3 the high frequency current is double in frequency of that of the low frequency current that any other ratio of frequencies may be used within limits. Also that the speed ratios between high speed and low speed synchronous motors of the systems shown in Figs. 1, 6 and 7 may vary from that of three to one illustrated. Also, the cam shafts may have a normal speed of two or more revolutions per hour instead of 1 R. P. M. as illustrated. Also, referring to the systems shown in Figs. 1 and 3 instead of employing an electro-magnet only on one side of the pendulum, two electro-magnets one on each side of the pendulum may be employed, in which case both electro-magnets are preferably energized either once or twice for each pendulum cycle. Referring to Fig. 3 the cams K^9 and K^{10} may be mounted on the winding shaft containing contacts **128—129**, it of course being understood that these two shafts normally operate at the same speed. Such a construction has already been illustrated in Fig. 1. The 3600 R. P. M. synchronous motors SM^2, SM^4, SM^5, SM^6, SM^7, SM^8 and SM^9 are preferably of the construction shown in Warren Patent No. 1,546,269, whereas the 1200 R. P. M. synchronous motors SM^1 and SM^3 are preferably of the construction shown in the Toewe Patent No. 1,788,813.

It is desired to point out that, if desired, the contacts **38—39** of the secondary clocks of Figs. 1, 6 and 7 and the contacts **97—98** of the secondary clocks of Fig. 2 may be omitted. These contacts have been provided to correct a secondary clock that is more than one minute fast. If a secondary clock is fast less than one minute it may be corrected because of the fact that the normal current is removed from the secondary clock during the sixtieth minute of the hour and these contacts contribute nothing insofar as correcting a secondary clock that is fast less than one minute and these contacts have been provided to correct a clock which is fast to a greater extent. If these contacts **38—39** or **97—98** are omitted it is possible to correct by the end-of-hour correcting means, shown in each of Figs. 1, 2, 6 and 7, a clock that is slow as much as fifty-nine minutes. This is done by imposing a plurality of corrections, one during each hour, of about two minutes each for the systems shown in Figs. 1, 6 and 7 and of about one minute each for the system shown in Fig. 2.

Also, if desired, the Fig. 2 and Fig. 7 constructions may be modified by including a contact controlled by the cam K^5 and open between the time indicating positions of 60:00 and 60:22 in the energizing circuit of relay R^2. This would cause the usual correction to take place in the same way at the end of hour position of the secondary clocks even during those times when the contacts **84—85** are closed which manifests that the shaft **50** is still tardy, and at the same time it would cause the extent of rewind to stay in step with the extent of corrections made upon the secondary clocks. In this case the contacts **54**, **55** and **56** may be omitted.

Fig. 8 structure.—Also, if desired, as shown in Fig. 8 of the drawings, an auxiliary source of alternating current, such as a standby alternating current generator, of either the rotary or the vibratory type, may be used to keep the secondary clocks operating approximately in accordance with the lapse of time during a cessation of the alternating current of regulated frequency. This auxiliary source of alternating current need not generate current of the precise frequency but should do so within possibly one half of one percent. In accordance with this modification a power-off relay PO is employed which is energized directly from the source of alternating current of regulated frequency, so that if this source of alternating current fails the relay PO will assume its retracted position. Dropping of the relay PO will result in the generation of alternating current. In the construction of Fig. 8 this is done by closure of the di-

rect current circuit including the battery **240**, the back contact **241** of the relay PO, and the interrupter contact **243** of the interrupter IN. This will cause pulsating direct current of approximately sixty cycles to flow in the primary winding **244** of the interrupter IN, resulting in the generation of alternating current of approximately 60 cycles in the secondary winding **245** of this interrupter IN, the interrupter armature being a tuned reed tuned to this frequency. Also, with the power-off relay in its retracted condition this auxiliary source of alternating current is through the back contact **246** of this relay PO applied directly to the double-throw contact **249** controlled by the master clock cam K^8 directly connected to the shaft **247** of any suitable master clock. This master clock is, however, preferably one of the type dominated by the source of alternating current of regulated frequency when such current is available such as shown in Figs. 1, 2 and 3 of this application and in my prior applications above referred to. The master clock is, however, not dominated by the auxiliary source of alternating current because the un-dominated master clock has better time keeping qualities than does the auxiliary source of alternating current.

Operation Fig. 8.—Referring to Fig. 8, normally when alternating current of regulated frequency is present and during the first fifty-nine minutes of the hour this alternating current flows to the low speed motor of the secondary clock S^8, which is exactly the same as that shown in Fig. 1. During the last minute of the hour the contacts shift, thereby applying current to the high speed synchronous motor (shown in Fig. 1) of the secondary clock S^8 and causes the secondary clock S^8 to be advanced until it reaches the zero minute position when the conacts **42—43** of the secondary clock S^8 open. When the master clock reaches this end-of-hour position the alternating current of regulated frequency is reapplied to the low speed wire L^8 so that thereafter the secondary clock will run in exact synchronism with the alternating current dominated master clock. During alternating current cessation the secondary clock S^8 is corrected in exactly the same manner as just explained. If a current cessation occurs the auxiliary source of alternating current will be substituted for the source of regulated frequency as long as the cessation continues, and there will be some error in the time indication of the secondary clock until it is corrected at the end of the hour. In those cases where alternating current of regulated frequency is not available at any time the master clock will not be so dominated in the Fig. 8 construction, in which case the end-of-hour corrections will be entirely relied upon to correct the secondary clocks in accordance with the master clock. In the Fig. 8 construction if a power failure exists while the master clock passes through the last minute of the hour the auxiliary source of alternating current will be used for correcting the secondary clocks. It is thus seen that the secondary clocks in the Fig. 8 system are kept in continuous operation except for a short time during correcting periods and that a clock that is less than two minutes slow or one that is less than one minute fast will be corrected.

Also, if desired the wires **45** and **46** may be connected together and connected directly to the low speed synchronous motor SM^3 of Fig. 1, the high speed synchronous motor SM^4 being omitted, but in this latter construction the gear ratio of the secondary clock is such that the shaft **31** (Fig. 1) makes one complete revolution during the flow of 213,000 cycles of current instead of during 216,000 cycles of current. Also the clock dial (see Fig. 9) will be constructed so that the minute indicating hand indicates time correctly, that is, advances to the next minute number on the dial for each 3600 cycles of current. It thus becomes apparent that the space between the 59th minute and the 60th minute on the dial (see Fig. 9) will span an arc that is only one-sixth as large as the arc spanned by each of the first fifty-nine minutes. It thus becomes apparent that if alternating current of regulated frequency is available the secondary clock will be held back fifty seconds during the last minute of each hour by the opening and reclosing of contacts **38—39** and **42—43** of the secondary clock. It is, of course, also understood that if the secondary clock should be fast to any extent up to fifty-nine minutes it will be corrected for reasons pointed out in connection with Fig. 1 and that if the secondary clock is slow to an extent of fifty seconds or less it will be corrected by being stopped for less than fifty seconds. In other words, in this modified construction the sixtieth minute on the clock dial spans only an arc of ten seconds of time and the clock if slow is stopped for less than fifty seconds at the end of the hour and is stopped the full fifty second period at the end of the hour if it was correct when the fifty-nine minute ten second position was reached. In this modified construction the auxiliary source of current IN (Fig. 8) should be correct within one percent so that a current cessation for a period of one hour will not produce an error of more than fifty seconds so that this error may be corrected at the end of such hour. Obviously since the secondary clock is corrected at the end of each hour a current cessation of any number of hours could not get the secondary clocks out of synchronism with each other or the master clock. A clock dial for this modified secondary clock construction has been shown in Fig. 9.

It is of course understood that each of the synchronous motors disclosed in this application is self starting. The self-starting feature of these synchronous motors is due to the fact that their rotors, which in each case constitutes a thin disk of permanent magnet steel, have sufficient residual magnetism to result in a hysteresis torque when a magnetic field passes through the plane of the disk. This residual magnetism also leaves permanent magnetic poles and results in synchronous operation when the disk is brought near to synchronous speed. Also, it should be understood that instead of having the corrections made hourly by having suitable cams on shafts rotated 1 R. P. H. these cams may be on shafts rotated one revolution in two hours or in any other desired time period.

Having thus shown and described several embodiments of clock systems exemplifying my invention it is desired to be understood that the particular arrangements, speed ratios, frequency ratios and the like have been selected to facilitate description of the invention and have not been illustrated as illustrations of the specific constructions preferably employed in practicing the invention. It should therefore be understood that various modifications and adaptations may be made to facilitate application of the inven-

tion to the problems encountered in practicing the invention without departing from the spirit of the invention except as demanded by the scope of the appended claims.

What I claim as new is:

1. In a clock system including a master clock and a secondary clock; the combination with a master clock which indicates standard time, a secondary clock normally indicating substantially the same time as indicated by said master clock including a high speed shaft and a self-starting synchronous motor means having a rotor mounted directly on said shaft, line wires connecting said master clock and said secondary clock, means including contact mechanism controlled by said master clock for applying operating alternating current to said line wires and to said secondary clock to cause said secondary clock to operate at substantially the same speed as said master clock so long as no cessation of alternating current occurs and to cause said high speed shaft to operate at increased speed for a time proportional to the time duration of such cessation after such cessation and to thereafter apply operating current to said line wires and said secondary clock to again operate said secondary clock at the speed of said master clock to cause said secondary clock to indicate substantially correct time after a temporary current cessation has occurred, and means including said means and also including other contact mechanism controlled by said master clock and including contact mechanism associated with said secondary clock effective between predetermined chronological conditions of said master clock and said secondary clock to correct said secondary clock periodically during times of no current cessation.

2. In a clock system; the combination with a source of alternating current; a master clock comprising a first means for measuring the passing of time and a second means for measuring the duration of a cessation of alternating current from said source; a secondary clock including a time shaft and a self-starting alternating current synchronous motor including a rotor for driving said shaft; line wires connecting said master clock and said secondary clock; means including said line wires and said second means for during the supply of alternating current operating said rotor at normal speed from said source and for causing said rotor to operate from current derived from said source at higher speed after each cessation of said alternating current for a time period equal to the normal speed divided by the difference between the higher speed and the normal speed and multiplied by the duration of such cessation; and other means including said line wires and said first means and also including contacts operated by said secondary clock for bringing said secondary clock into chronological synchronism with said master clock periodically during times of no current cessation.

3. In combination a master clock shaft rotated to substantially correctly manifest the passing of time and to indicate standard time, a source of alternating current, a secondary clock including a high speed shaft having a low speed and a high speed rotor mounted thereon, said secondary clock also including a low speed stator associated with said low speed rotor and a high speed stator associated with said high speed rotor, line circuit means connecting said master clock and said secondary clock, means including contacts operated by said master clock shaft to control said line circuit means to cause said low speed stator to be energized during a first time interval of a time period and to cause said high speed stator to be energized during a second time interval of said time period, means controlled by said secondary clock when it reaches a predetermined chronological condition to prevent further operation of said secondary clock by said high speed stator, and means including other contacts operated by said master clock shaft for controlling said line circuit means after each cessation of said alternating current for energizing said high speed stator for a time inversely proportional to the difference of the speeds of said rotors when driven by their respective stators divided by the speed of the low speed rotor when driven by its stator and directly proportional to the duration of said current cessation.

4. In combination a master clock shaft rotated to substantially correctly manifest the passing of time and to indicate standard time, a source of alternating current, a secondary clock including a high speed shaft having a low speed and a high speed rotor mounted thereon, a low speed stator associated with said low speed rotor and a high speed stator associated with said high speed rotor, line circuit means connecting said master clock and said secondary clock, means including contacts operated by said master clock shaft to control said line circuit means to cause said low speed stator to be energized during a first time interval of a time period and to cause said high speed stator to be energized during a second time interval of said time period, and means controlled by said secondary clock when it reaches a predetermined chronological condition to prevent further operation of said secondary clock by said high speed stator, whereby said secondary clock starts from said predetermined chronological condition at the beginning of each time period.

5. In a clock system, a first source of alternating current, a second source of alternating current, a master clock shaft, reduction gearing, a self-starting synchronous motor, a secondary clock having a time shaft connected directly and permanently through said reduction gearing to said self-starting synchronous motor, line wires extending from said master clock to said secondary clock, means controlled by said master clock for normally supplying said self-starting synchronous motor with alternating current from said first source over said line wires, means effective in response to a current cessation from said first source for connecting said secondary source to said synchronous motor over said line wires for a time to operate said synchronous motor substantially the same number of additional revolutions that it would have operated had no current cessation taken place, and other means including contacts on said master clock and contacts on said secondary clock effective between predetermined chronological conditions of said master clock and said secondary clock to correct said secondary clock, said other means functioning periodically during times of no current cessation.

6. In a clock system, the combination with two self-starting synchronous motors, two sources of alternating current of regulated frequency one source being of high frequency and the other source being of low frequency with said frequencies sufficiently close to each other so that both are capable of operating said self-starting synchronous motors but at different speeds, an es-

cape mechanism including an oscillatory member, a main spring for driving said escape mechanism, an electro-magnet for holding said oscillatory member at rest, a rectifier, a direct current for energizing said electro-magnet derived by the rectification of alternating current from one of said sources by said rectifier so that said electro-magnet is deenergized upon cessation of current from said one source, rewinding means for rewinding said main spring driven by one of said synchronous motors energized only when said main spring is partly unwound providing there is no current cessation, a time shaft normally indicating standard time driven by the other of said synchronous motors which other synchronous motor is energized by alternating current of said low frequency source when said main spring is fully wound and there is no cessation of current from said one source and energized by current of said high frequency when said main spring is partly unwound and there is no cessation of current from said one source, and a bucking coil on said electro-magnet having a resistance to render said oscillatory member slow releasing to the same extent that the other of said synchronous motors will gain as compared with the number of cycles applied thereto when such synchronous motor is temporarily deenergized followed by high frequency energization thereof immediately after a temporary current cessation, whereby said escape mechanism will accurately measure the time lost by said time shaft during a current cessation and whereby said time shaft indicates standard time when said main spring is fully wound, and a secondary clock controlled by said time shaft.

7. In a primary-secondary clock system, the combination with a source of alternating current of regulated frequency regulated to correctly manifest the passing of time, a master clock including escapement mechanism for substantially correctly manifesting the passing of time during cessation of said alternating current and for indicating standard time and including alternating current controlled means to manifest the passing of time correctly as determined by the alternating current cycle passage of said source during the supply of alternating current from said source, a secondary clock including a self-starting synchronous motor means having a rotor, line wires connecting said master clock and said secondary clock, means including contact mechanism operated by said master clock for controlling the application of alternating current over said line wires to said secondary clock to cause said secondary clock to operate in perfect synchronism with said master clock during the presence of said alternating current of regulated frequency and effective after each cessation of alternating current to cause said rotor to operate at increased speed for a time period proportional to said cessation and at a rate so that said secondary clock will indicate atfer such period substantially the same time that it would have indicated had no current cessation occurred, and means including said means and also including additional contact mechanism operated by said master clock and contacts operated by said secondary clock to periodically correct said secondary clock with respect to said master clock during times when no current cessation occurs.

8. In a two-unit master clock, the combination with two self-starting synchronous motors, two sources of alternating current one source being of high frequency and the other source being of low frequency with said frequencies sufficiently close to each other so that both are capable of operating said self-starting synchronous motors but at different speeds, an escape mechanism including an oscillatory member, a main spring for driving said escape mechanism, an electro-magnet for holding said oscillatory member at rest, a rectifier, a direct current for energizing said electro-magnet derived by the rectification of alternating current by said rectifier from one of said sources so that said electro-magnet is deenergized upon cessation of current from said one source, rewinding means for rewinding said main spring driven by one of said synchronous motors energized only when said main spring is partly unwound providing there is no current cessation, a time shaft normally indicating standard time driven by the other of said synchronous motors which other synchronous motor is energized by alternating current of said low frequency source when said main spring is fully wound and there is no cessation of current from said one source and energized by current of said high frequency when said main spring is partly unwound and there is no cessation of current from said one source, and a bucking coil on said electro-magnet having a resistance to render said oscillatory member slow releasing to the same extent that the other of said synchronous motors will gain as compared with the number of cycles applied thereto when such synchronous motor is temporarily deenergized followed by high frequency energization thereof immediately after a temporary current cessation, whereby said escape mechanism will accurately measure the time lost by said time shaft during a current cessation and whereby said time shaft indicates standard time when said main spring is fully wound, a secondary clock including a time shaft and a third synchronous motor for driving said secondary clock time shaft, a line circuit connecting said master clock and said secondary clock, two pairs of contacts operated by said time shaft of said secondary clock one pair opened for a short arc of movement of said time shaft at the end of each revolution thereof and the other pair opened for a short arc of movement of said time shaft just before the end of each revolution thereof, a filter allowing only the free flow of high frequency alternating current connected in series with said one pair of contacts, a filter allowing only the free flow of low frequency alternating current connected in series with said other pair of contacts, said serially connected contacts and filters being connected in multiple with each other and then in series with said third synchronous motor and said line circuit, and contacts controlled by the time shaft of said master clock for applying alternating current of low frequency during a first portion of a revolution of each time shaft of said master clock and for applying alternating current of high frequency during the remaining portion of such revolution of said time shaft of said master clock to said line circuit.

9. In a synchronous motor clock system, the combination with a secondary clock including a time shaft, synchronous motor means for driving said time shaft including a high speed circuit branch and a low speed circuit branch for operating said time shaft at high speed or a low speed respectively depending upon whether said high speed circuit branch or said low speed circuit branch is energized, a pair of contacts included in series in said high speed circuit branch controlled by said time shaft and opened when said

time shaft reaches the end of a time period position and remaining open for a short arc of movement of said time shaft, and a master clock effective to energize said high speed circuit branch with alternating current during the last portion of such time period as manifested by said master clock and for energizing said low speed circuit branch with alternating current during the remaining earlier portion of such time period.

10. In an alternating current clock system, a source of alternating current, a master clock including two units one of which substantially accurately reflects the passing of time and the other of which in combination with the first unit measures the duration of a cessation of alternating current from said source, a secondary clock having a time shaft, two synchronous motors having different synchronous speeds when energized by alternating current from said source having their rotors secured to said shaft, contacts controlled by said time shaft open for a short interval at the end of each time period as reflected by said secondary clock included in series with the synchronous motor having a high speed, a transformer for each of said synchronous motors, a filter for one transformer allowing only pulsating current of one polarity to flow through it included in series with the primary winding of one of said transformers, a filter allowing only pulsating current of the opposite polarity to flow through it included in series with the primary winding of the other of said transformers, a circuit including the secondary winding of one of said transformers and said low speed synchronous motor in series, another circuit including the secondary winding of the other of said transformers said high speed synchronous motor and its associated contacts in series, a line circuit, and means controlled by said master clock for transmitting over said line circuit and to the filters of said secondary clock pulsating current of one polarity after each current cessation and during the latter portion of said time period as reflected by said master clock and for transmitting over said line circuit and to the filters of said secondary clock pulsating current of the opposite polarity during the remaining portion of such period.

11. In a synchronous motor clock system, the combination with a secondary clock including a time shaft, two synchronous motors each capable of directly driving said time shaft which motors if energized separately by currents of the same frequency will operate said time shaft at different speeds, a source of pulsating current of one polarity, a source of pulsating current of the opposite polarity, both said sources of pulsating current being of the same frequency, a pair of contacts included in series with the synchronous motor which drives said time shaft at the higher speed, a line circuit, a rectifier for allowing pulsating current of one polarity to flow included in an energizing circuit for energizing said motor driving said time shaft at the higher speed, a rectifier for allowing pulsating current of the opposite polarity to flow included in an energizing circuit for the other of said synchronous motors, and a master clock for applying pulsating current of said one polarity through the medium of said line circuit to said rectifiers during the last portion of a time period and for applying pulsating current of the opposite polarity to said rectifiers through the medium of said line circuit during the remaining earlier portion of said time period.

12. In a synchronous motor clock system, the combination with a secondary clock including a time shaft, two synchronous motors each capable of directly driving said time shaft which motors if energized separately by currents of the same frequency will operate said time shaft at different speeds, a source of alternating current, a pair of contacts controlled by said time shaft and included in series with one of said synchronous motors which motor if energized by said alternating current drives said time shaft at the higher speed, two transmitting circuits one including said pair of contacts and the said one synchronous motor and the other transmitting circuit including the other synchronous motor, and a master clock for applying periodic current from said source to said one transmitting circuit during the last portion of a time period for correcting said secondary clock and for applying periodic current from said source to the other of said transmitting circuits during the remaining earlier portion of such time period for advancing said secondary clock in accordance with the lapse of time, whereby a fast clock is retarded because said other circuit is closed during less than said period of time and a slow clock is advanced by said one synchronous motor when included in said one circuit.

13. In a synchronous motor clock system, the combination with a secondary clock having a high speed circuit branch and a low speed circuit branch, a time shaft included in said secondary clock, a gear train for driving said time shaft, synchronous motor means directly and continuously operatively connected to drive said time shaft through the medium of said gear train, said synchronous motor means being common to both of said circuit branches and operating said time shaft at a high speed when said high speed circuit branch is energized by alternating current and operating said time shaft at a low speed when said low speed circuit branch is energized by alternating current, a pair of contacts in said high speed circuit branch controlled by said time shaft and opened when said time shaft assumes the zero time position and for a short arc of movement of said time shaft beyond such zero time position, a source of alternating current, and means including a master clock having a master time shaft and associated contact mechanisms for energizing said high speed circuit branch during the latter portion of a revolution of said master time shaft and also after termination of a cessation of alternating current from said source for a time proportional to the duration of such cessation and for applying energizing current to said low speed circuit branch when said high speed circuit branch is not energized.

14. A time indicating system comprising in combination, a master clock, a secondary clock including a synchronous motor and time manifesting means driven by said synchronous motor, means including contacts controlled by said master clock and a circuit leading from said master clock to said secondary clock to at times supply fluctuating current of one character to said secondary clock over said circuit to operate said secondary clock through the medium of its synchronous motor at a normal speed and to at other times supply fluctuating current distinctive in character from said current of one character to operate said secondary clock through the medium of its synchronous motor at a higher than normal speed, and means controlled by said secondary clock to at times block the flow of one

of said currents and to at other times block the flow of the other of said currents.

15. A time indicating system according to the preceding claim wherein the characters of currents comprise two currents of different frequencies.

16. A time indicating system according to claim 14 wherein the characters of currents comprise pulsating currents of the same frequency but of different polarities.

17. A time indicating system comprising in combination, time manifesting means, a gear train for driving said time manifesting means, a two speed rotary synchronous motor means including two circuits and for driving said gear train, said motor means being constructed and arranged to operate at one synchronous speed when alternating current from a regulated frequency source is applied to one of said circuits and to operate at a higher synchronous speed when current from the same source of alternating current is applied to the other circuit thereof each of said synchronous speeds bearing a constant ratio to the frequency of said alternating current, a master clock, and means controlled by said master clock and said gear train to at times energize one circuit of said synchronous motor means and to at other times energize said another circuit of said synchronous motor means by alternating current from said regulated frequency source.

18. A time indicating system comprising in combination, time manifesting means, a shaft for driving said time manifesting means, a two speed rotary synchronous motor means including a first circuit branch and a second circuit branch, said motor means being constructed and arranged to operate at one synchronous speed when alternating current from a regulated frequency source is applied to said first circuit branch and operate at a higher synchronous speed when current from the same source of alternating current is applied to said second circuit branch each of said synchronous speeds bearing a constant ratio to the frequency of said alternating current, a master clock, and means controlled by said master clock and said shaft to at times energize said first circuit branch of said synchronous motor means and to at other times energize said second circuit branch of said synchronous motor means by alternating current from said regulated frequency source.

19. In combination, a master clock including a time shaft which by its rotation substantially correctly manifests the passing of time, a source of alternating current having its frequency regulated to manifest accurately by cycle passage the passing of time and available at said master clock, a secondary clock including time manifesting means and a synchronous motor for driving said means at a speed to indicate the passing of time in accordance with the cycle passage of the alternating current applied thereto and also including correcting means for operating its time manifesting means at a higher speed when energized by alternating current of the same frequency, a circuit extending from said master clock to said secondary clock controlled by contacts operated by said time shaft for supplying alternating current from said frequency regulated source of alternating current to said synchronous motor, a second circuit extending from said master clock to said secondary clock and connected to said correcting means to at times operate said time manifesting means at said higher speed, and means controlled by the time shaft of said master clock for at times applying alternating current from said frequency regulated source to said second circuit.

20. In an alternating current clock system, the combination with a source of alternating current having its frequency regulated to correctly manifest the passing of time, a master clock including a first means for measuring the lapse of time in accordance with the number of cycles of alternating current received and a second means for measuring the duration of a cessation of such alternating current, a secondary clock including a synchronous motor means normally energized by alternating current from said source to drive said secondary clock at a normal rate, advancing means including said synchronous motor means for driving said secondary clock at an excessive rate, and correcting means for periodically correcting said secondary clock by rendering said advancing means active which corrects said secondary clock in acordane with time periods measured by said first means when no current cessation occurs and corrects said secondary clock in accordance with time periods measured by said second means when a current cessation has taken place since said secondary clock was last corrected.

21. In combination; a master clock; a secondary clock including time manifesting means and a synchronous motor for driving the same; a source of alternating current of regulated frequency supplying current to a point adjacent said master clock; a line circuit connecting said clocks; means including said line circuit and including contacts controlled by said master clock for normally supplying current from said source to said secondary clock to cause it to manifest correctly the passing of time so long as said contacts are closed and no cessation of alternating current occurs and for supplying current to said secondary clock to cause it to operate at a higher than normal rate after each alternating current cessation for a time proportional to said cessation to correct said secondary clock, and other means including said line circuit and other contacts controlled by said master clock for periodically supplying current to correct said secondary clock irrespective of a current cessation.

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