March 9, 1943. O. H. DICKE 2,313,466

ELECTRIC CLOCK SYSTEM

Filed Dec. 14, 1938 5 Sheets-Sheet 1

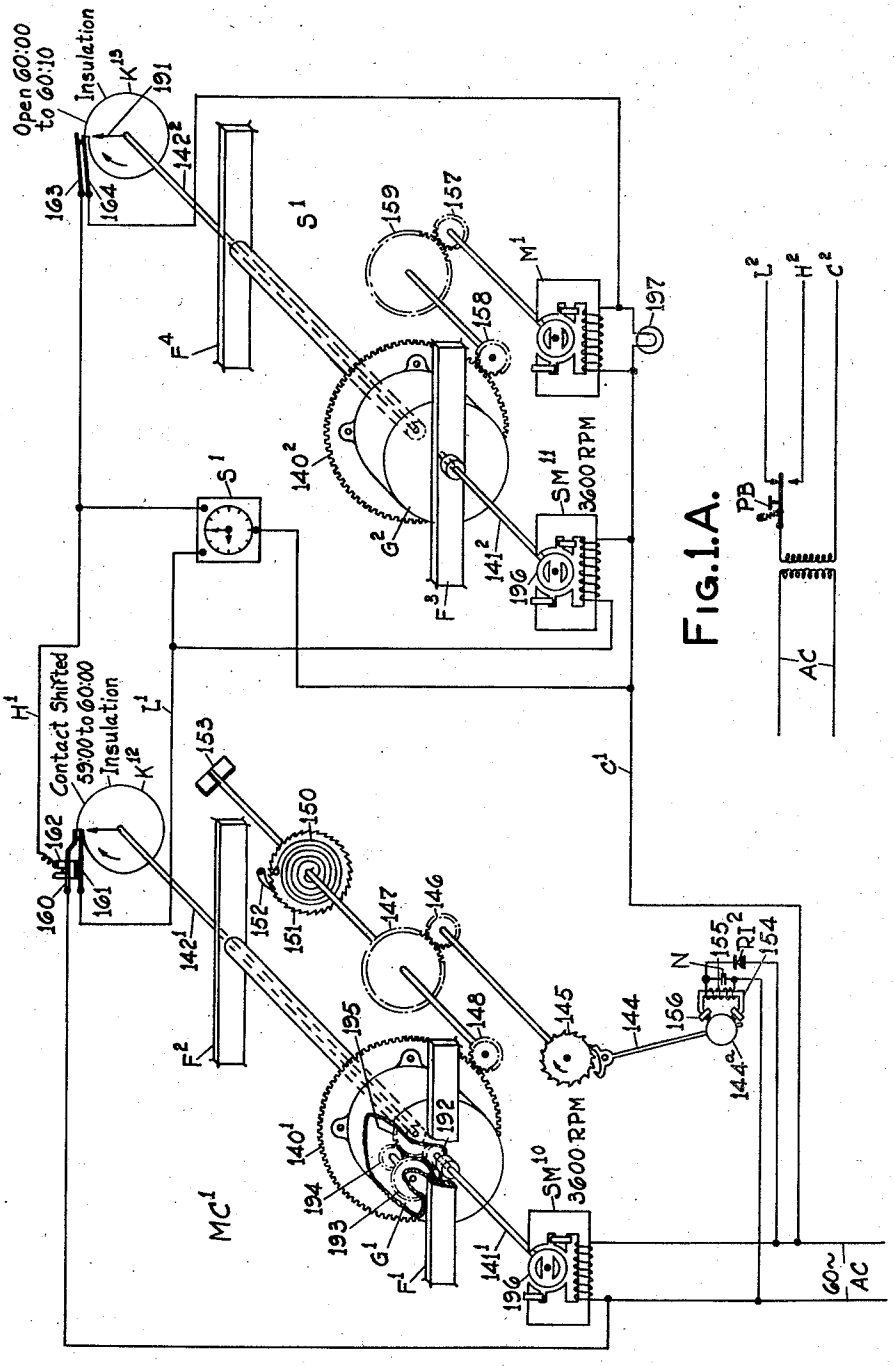


FIG. 1.

FIG. 1.A.

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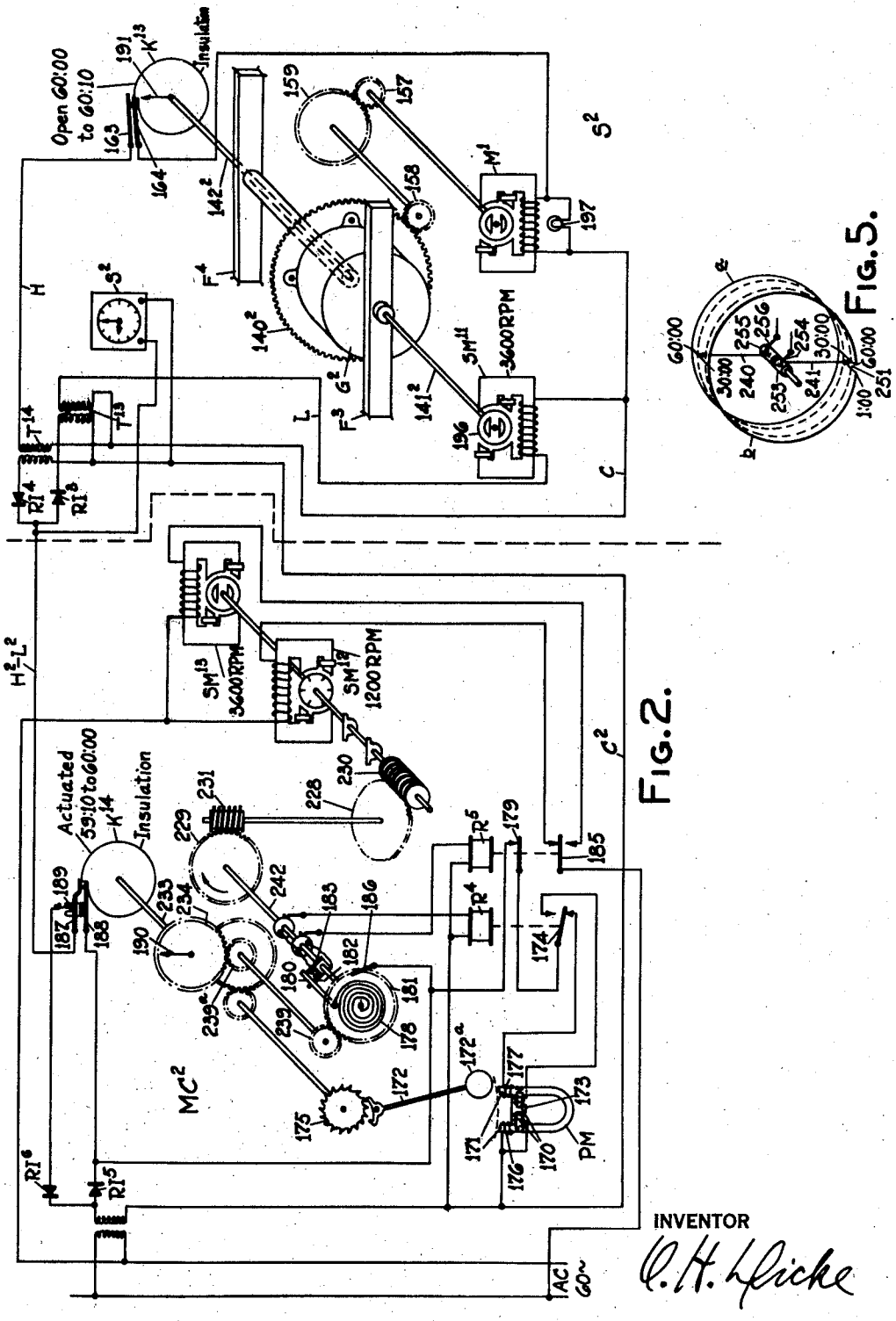


FIG. 2.

FIG. 5.

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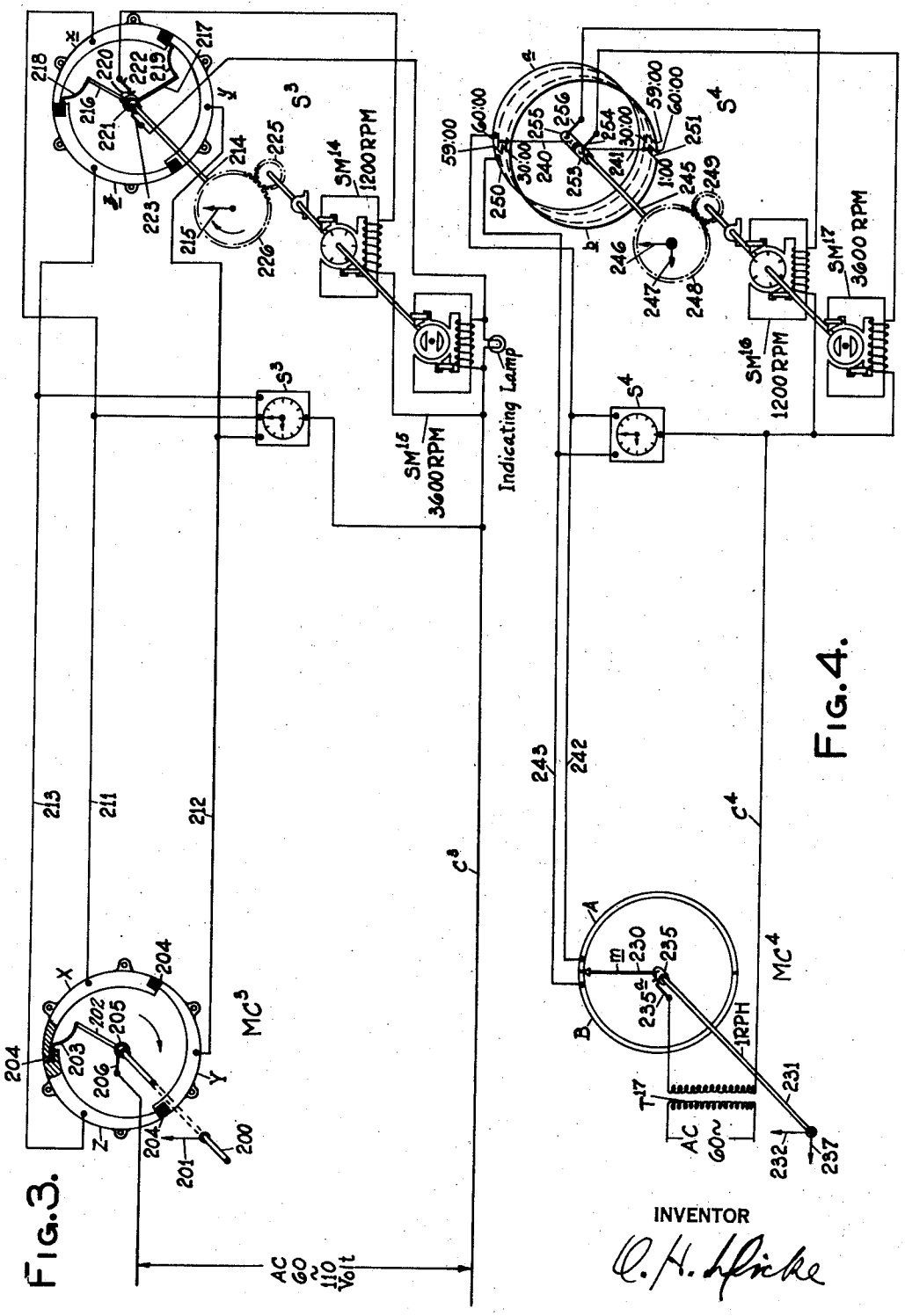


FIG. 3.

FIG. 4.

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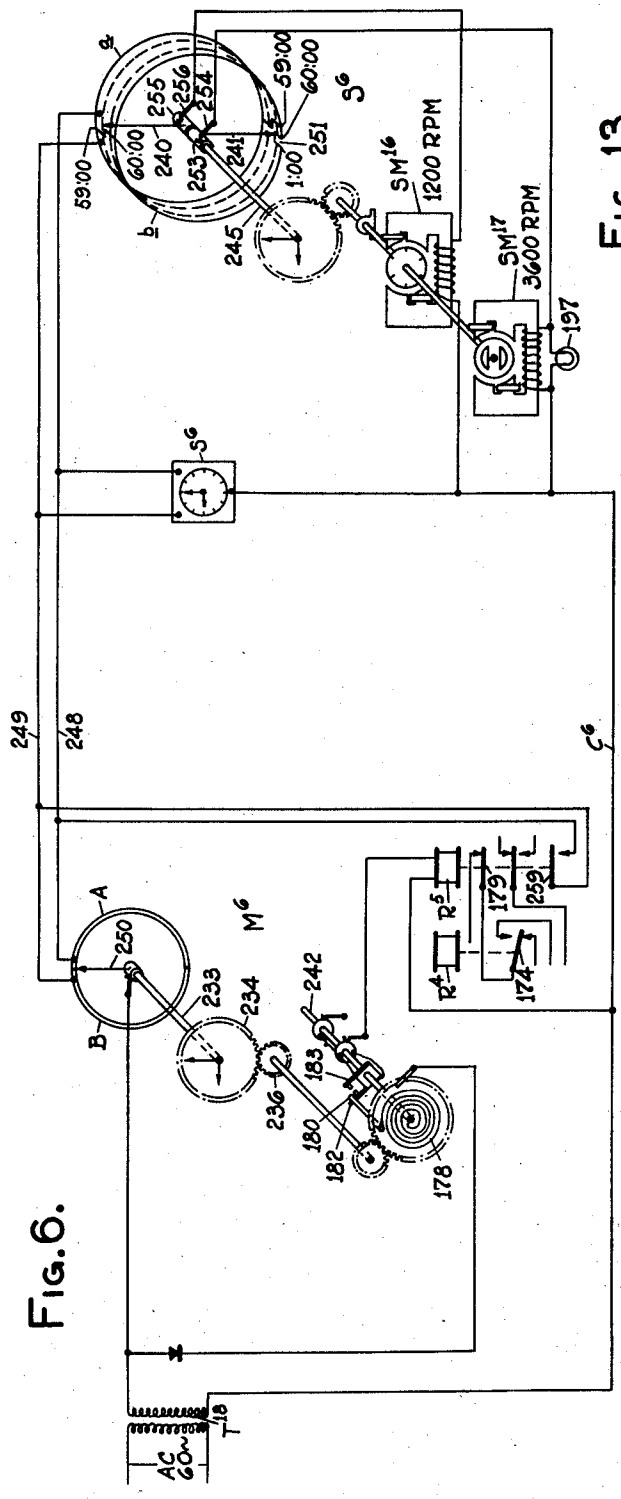


FIG. 6.

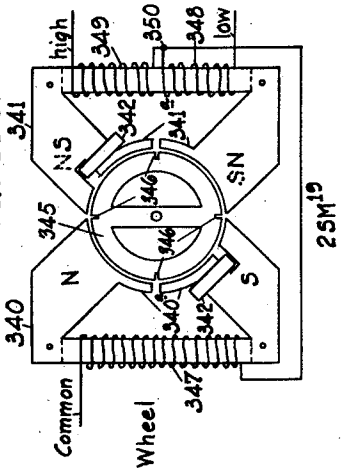


FIG. 13.

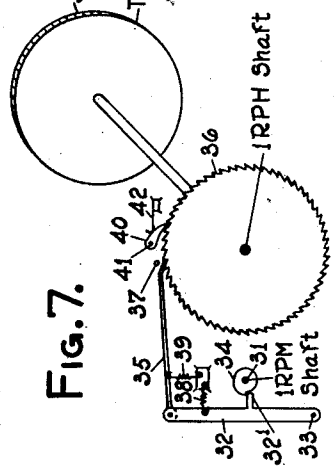


FIG. 7.

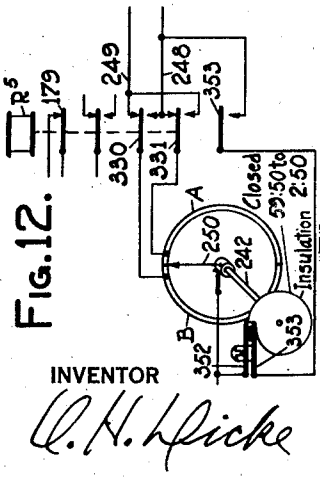


FIG. 12.

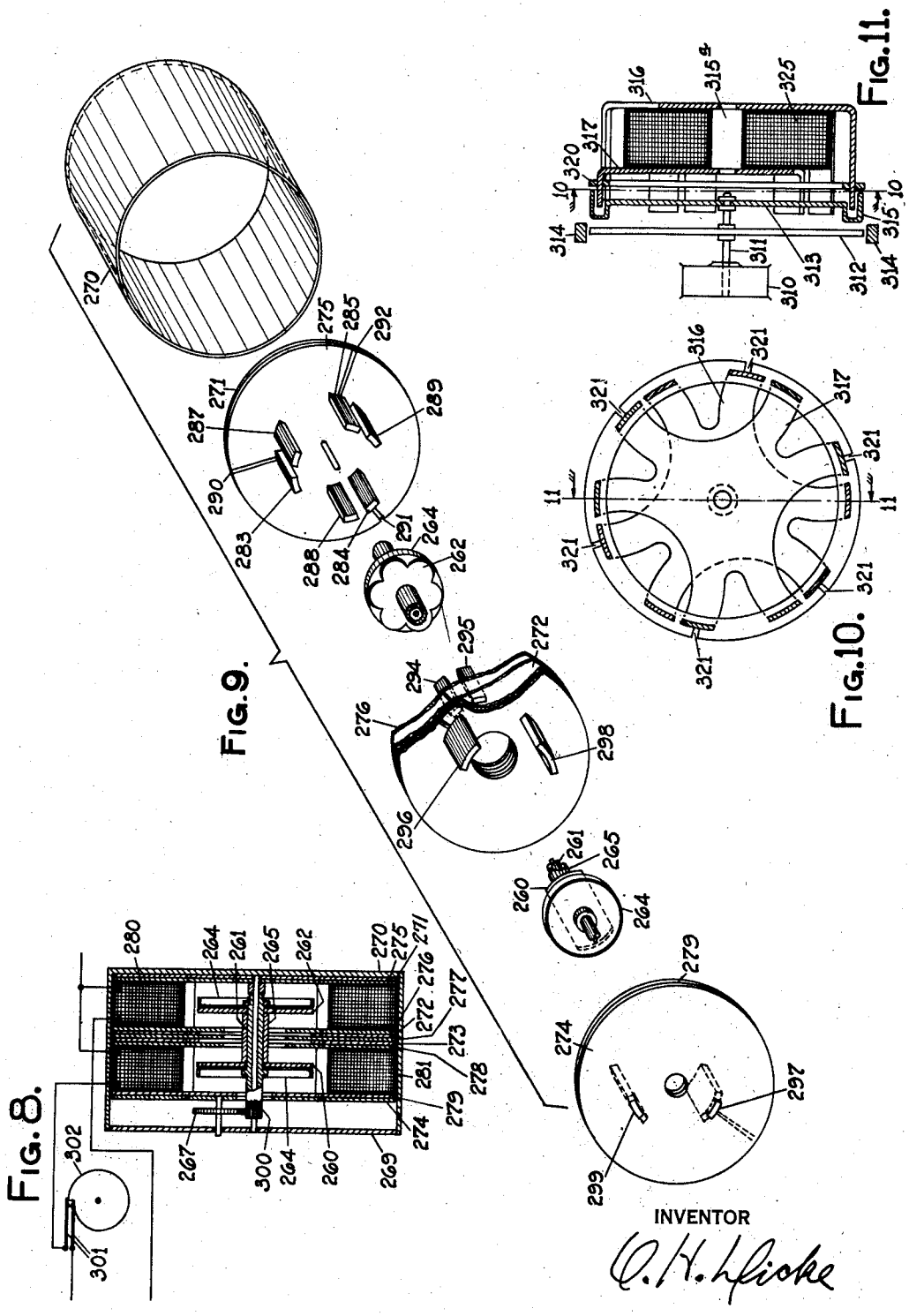
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Patented Mar. 9, 1943 2,313,466

UNITED STATES PATENT OFFICE

2,313,466

ELECTRIC CLOCK SYSTEM

Oscar H. Dicke, Rochester, N. Y.

Application December 14, 1938, Serial No. 245,700

23 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 at a higher speed from the same source of 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.

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.

Another object of the present invention resides in the provision of means to accelerate a master clock when it is tardy with respect to a synchronous motor and to retard such master clock when it is fast with respect to such synchronous motor during the presence of alternating current and to adjust its time measuring mechanism to normal during a cessation of alternating current. The alternating current mentioned being derived from a source having its frequency regulated to manifest accurately the passing of time.

Another object of the present invention resides in the provision of a plurality of line circuits connecting a master clock and one or more secondary clocks, these circuits being energized in sequence by the master clock, and to provide circuit selecting means for each secondary clock, which secondary clock has a high speed driving circuit and a low speed driving circuit, such that the high speed driving circuit is connected to the then energized line circuit when the secondary clock is slow, but the low speed driving circuit is so connected when the secondary clock is correct, other means being provided to hold the secondary clock at stop when it is fast.

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 form of the invention in which the master clock comprises a time shaft driven during current presence by a synchronous motor and during current cessation by a normally braked escapement clock, and in which the secondary clock includes a time shaft driven by two different synchronous motors through gear trains having different gear ratio;

Fig. 1A shows how a push button manually operated may correct a secondary clock;

Fig. 2 illustrates a modified master clock from that shown in Fig. 1 for controlling a secondary clock such as illustrated in Fig. 1, but through the medium of a single circuit, rectifiers being used to isolate two different currents into separate synchronous motors, and in which the master clock is automatically regulated from time to time so as to cause it to run in accordance with the rate of cycle passage only so long as there is no current cessation;

Fig. 3 shows a modification of time control system which is conveniently called a correspondence type time control system whereby a simple

commutator on a continuously running shaft of a master clock such as shown in Figs. 1 and 2 may control a secondary clock over four wires;

Fig. 4 shows a time control system similar to that shown in Fig. 3 but employing only three line wires instead of four,

Fig. 5 shows a modified secondary clock contact structure for the system shown in Fig. 4, this modified structure when used in the system of Fig. 4 causes a secondary clock to be corrected only to the extent of a predetermined fraction of its then tardiness during each of successive equal time intervals similar to the system shown in Fig. 3;

Fig. 6 shows a time control system employing the master clock shown in Fig. 2 and employing a secondary clock such as shown in Fig. 4 but employing additional contact mechanism for at times connecting the two control lines together;

Fig. 7 illustrates the mechanism that is preferably employed when a secondary clock is used for stamping time cards, or the like.

Fig. 8 shows a double synchronous motor for secondary clock control and correction.

Fig. 9 shows an exploded perspective of the motor shown in Fig. 8.

Fig. 10 shows in section a modified form of double synchronous motor taken on the line 10—10 of Fig. 11 as viewed in the direction of the arrows.

Fig. 11 is a section of the same motor taken on the line 11—11 of Fig. 10.

Fig. 12 shows how Fig. 6 may be modified when using synchronous motors SM^{16} and SM^{17}, the double motors of Fig. 8 or 11 or the two speed synchronous motor of Fig. 13 in the secondary clocks; and

Fig. 13 shows a two speed synchronous motor which constitutes either a two pole or a four pole motor depending on which of its two circuits is energized.

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 regulated (Fig. 2) so as to run in synchronism with alternating current cycle passage, or by correcting a master electric clock in accordance with the duration of a current cessation during each current cessation (Fig. 1). The secondary clocks may be used as a tower clock by using a separate unit for each dial, to operate record sheets, as bell ringers or for any other program purpose.

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; Ser. Nos. 729,079 and 729,080 filed June 5, 1934, and now respectively Patents Nos. 2,248,165 and 2,185,334 granted respectively on July 8, 1941, and January 2, 1940; Ser. No. 239,538 filed November 8, 1938, 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.

The subject matter of Figs. 1, 1A, 2 and 13 is not specifically claimed herein but is claimed in divisional application Ser. No. 472,698, filed January 18, 1943.

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. 3, 4, and 6. 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 stator acting on a higher speed, fewer poles, rotor, see Figs. 3 and 4, for instance. In each of Figs. 3 and 4 the secondary clock is advanced after each alternating current cessation although not necessarily immediately 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 no special release is necessary.

In the correspondence form of invention shown in Figs. 3 and 4 each secondary clock includes two motors capable of driving the secondary clock at different speeds per cycle, and these motors near the end of each period as reflected by such secondary clock are each energized or not energized dependent upon whether or not the secondary clock is late or on time. If late the motor producing high speed operation is energized if on time the motor producing normal speed operation is energized near the end of a time period. These systems of Fig. 3 and Fig. 4 also include means for stopping the secondary clock when it reaches the end of such period if the secondary clock is fast.

In the correspondence type of clock system construction of Figs. 3 and 4 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

Referring to Fig. 1, the system shown therein is in certain respects different from that shown in Figs. 3, 4, 6 and 12, particularly in that all corrections of secondary clocks is made at the end of the first hour, or some other time interval, as manifested by the master clock, that is, there is no repeated correction as in Figs. 3, 4, 6 and 12.

In this form of my invention the master clock and the secondary clocks, only one having been shown structurally are very much alike. That is, each includes a rotatable gear box containing reduction gearing including pinions 192, 194 and gears 193 and 195, the gear boxes G^1 and G^2 being preferably oil filled. This reduction gearing preferably including sufficient friction or some worm gears, so that if the gear box is rotated and the synchronous motor whose rotor 196 projects from the gear box is not energized this rotor will be rotated at the same speed as the gear box, that is, will be stationary with respect to the gear box.

Referring to Fig. 1 the gear boxes G^1 and G^2 are pivotally mounted in stationary frames F^1, F^2, F^3 and F^4. To one end of these gear boxes is fastened a gear 140^1 or 140^2 which is preferably of slightly larger diameter than the gear box di-

ameter. Concentric with and mounted within one of the bearings of the gear box is a motor shaft 141¹ or 141² on which is mounted the rotor 196 of a synchronous motor, these motors having been designated SM¹⁰ and SM¹¹. Concentric with and mounted within the other bearing of the gear boxes G¹ and G² is a minute shaft (1 R. P. H.) designated 142¹ for the master clock and 142² for the secondary clock these minute shafts carry insulating cams K¹² and K¹³, respectively. The gear ratio of the pinions 192—194 and gears 193—195 within the gear boxes G¹ and G² is such that if these gear boxes are held stationary and the synchronous motors SM¹⁰ and SM¹¹ are rotated at synchronous speed by current from the regulated frequency current source, the minute shafts 142¹ and 142² will rotate clockwise at a speed of one revolution per hour (1 R. P. H.).

The gear 140¹ of the master clock MC¹ is at times, namely, during power failures, driven by any suitable escapement clock including preferably a pendulum 144 having a magnetic bob 144ª, an escape wheel 145, a driven pinion 146, and gear reduction means conventionally indicated by the pinion 148, and the gears 140¹ and 147. This escapement clock also includes a main spring 150 anchored to a hand winding ratchet wheel 151 driving the gear 147. This ratchet wheel 151 is kept from unwinding by the ratchet pawl 152 and may be hand wound by the key 153. Suitable electric motor winding means such as shown in my prior applications above referred to may be used if desired. The pendulum 144 is normally, that is when alternating current is available, held at rest, or is braked, by the electro-magnet 154—155 having its projecting legs surrounded individually by slugs or short circuited rings 156 of low resistance. The winding 155 of this electro-magnet is normally energized by direct current derived through the medium of a rectifier RI² from the regulated alternating current source. The slugs or bucking coils 156 and the rectifier RI² is used to render the electro-magnet slow releasing. This slow releasing feature is employed to cause the escapement clock mechanism to drive the gear box G¹ about its pivot for a slightly shorter time than the actual current cessation in order that the shaft 142¹ may accurately indicate standard time after a current cessation. In this connection it is desired to point out that a synchronous motor of the kind contemplated, and in fact any commercial synchronous motor, will coast for a time so that it will not be stationary during the entire current cessation. It has been observed that such a synchronous motor will, if deenergized for one second, be tardy only to the extent of about a half second. The slugs 156 are of such resistance that a current cessation of say two seconds will cause the two pole rotor 196 to coast thirty revolutions (one-half second) and will cause the escapement clock to operate for one and one-half seconds.

Referring now to the secondary clock S¹ of Fig. 1, the gear 140² is at times, namely when the secondary clock is being corrected, driven by an auxiliary synchronous or induction motor M¹ through the medium of a gear train including pinions 157 and 158 and gear 159. The gear ratio of this gear train is preferably such that if the motor M¹ is operated at normal speed and the synchronous motor SM¹¹ is deenergized, the shaft 142² will be rotated at about sixty times normal speed, that is, at 60 R. P. H. instead of 1 R. P. H. The synchronous motor SM¹¹ may drive the shaft 142² in exactly the same way as synchronous motor SM¹⁰ may drive shaft 142¹.

Operation Fig. 1

Normally, that is when alternating current of regulated frequency is available, the alternating current from the regulated source energizes the brake magnet 154—155 and holds the escapement portion of the master clock MC¹ at rest. At the same time the synchronous motor SM¹⁰ drives the shaft 142¹ and the cam K¹² at 1 R. P. H. through the medium of the gear reduction 192—195 within the then stationary gear box G¹. Also, this alternating current of regulated frequency flows through contacts 160—161 through the line L¹, through winding of synchronous motor SM¹¹, and through common return wire C¹, back to the power line, and causes the shaft 142² and the cam K¹³ to be rotated at 1 R. P. H. When the master clock cam K¹² reaches the 59:00 minute minute position the contacts 160—161 open and the contacts 160—162 close. The secondary clock motor SM¹¹ stops due to deenergization of line wire L¹ and if the secondary clock S¹ was less than fifty-nine seconds fast the contacts 163—164 of the secondary clock will not yet have opened. The application of the regulated alternating current frequency to the high wire H¹ causes the motor M¹ of the secondary clock to be operated to cause the minute shaft (1 R. P. H.) 142² to be driven at about sixty times normal speed. This high speed rotation of the shaft 142² and cam K¹³ will, however, only continue until the contacts 163—164 operated by this cam K¹³ open. The secondary clock may therefore be slow as much as fifty-nine minutes and be brought to the end-of-hour position during the last minute of actual time as indicated by the master clock. When the master clock now reaches the end-of-hour or sixty minute position, the contacts 160—162 open and the contacts 160—161 reclose after which the secondary clock will run in exact synchronism with the master clock until the fifty-nine minute position of both clocks is reached providing there has been no current cessation. If a current cessation occurs during a certain hour and it does not exceed fifty-nine minutes the secondary clock will be corrected during the sixtieth minute of such hour. Obviously, if desired, corrections of longer outages than one hour may be corrected if the discs or cams K¹² and K¹³ are driven by two hour or three hour shafts.

Fig. 1A illustrates how secondary clocks, such as shown in Fig. 1, may be manually corrected. Let us assume that a person has tuned his radio set to receive the usual Arlington or any other time signal audibly over such set. He will depress the push button PB from one to several minutes before the end of the hour as a result of which all secondary clocks will assume the sixty minute or end of hour position. When he hears the sound manifesting the end-of-hour period he will release the push button PB as a result of which all secondary clocks will again be operated at normal speed and will be correct. A plurality of secondary clocks may be connected in multiple and corrected in like manner.

Fig. 2 structure

The secondary clock of Fig. 2 is identical to the secondary clock of the system shown in Fig. 1 except for the addition of the rectifiers RI³ and RI⁴ and transformers T¹³ and T¹⁴. These rectifiers RI³ and RI⁴ and transformers T¹³ and T¹⁴ are really filtering apparatus so that it can still be

said that the secondary clocks of Figs. 1 and 2 are identical.

Referring to the master clock of Fig. 2, this clock is an escapement clock in which the pendulum is not dominated like it is in the Fig. 1 Ser. No. 239,538 construction, but is controlled or regulated so as to at times run faster or slower than its normal adjusted correct time measuring operating rate. In this construction there is preferably provided a permanent magnet PM which has leakage poles of soft iron 170 projecting inwardly from the poles of the permanent magnet. It is also provided with soft iron extensions 171. This permanent magnet is placed directly below the pendulum 172 having a soft iron bob 172a and the pendulum is then adjusted to keep correct time. The leakage poles are provided with a sucking winding 173, so to speak, which is at times energized by direct current derived from the regulated alternating current system through the medium of a rectifier RI5 and flowing through the front contact 179 of relay R5 and the front contact 174 of the relay R4. The flow of this current is in such a direction through the winding 173 that the magneto-motive force produced thereby aids the magneto-motive force of the permanent magnet and causes a large part of the flux emitted by said permanent magnet to be diverted away from the pendulum so that gravity is no longer magnetically aided to any appreciable extent and the pendulum operates at a lower frequency. In a similar manner the soft iron extensions 171 are provided with boosting windings 176 and 177 which when energized by direct current derived through the rectifier RI5 through the front contact 179 of relay R5, and the back contact 174 of relay R4 causes the apparent strength of the permanent magnet PM to be increased thereby still further magnetically aiding gravity and causing the pendulum to operate at a faster rate or frequency. The windings 173, 176 and 177 are when energized so poled as to aid the permanent magnet so as to avoid weakening of the permanent magnet as might be the case if they were bucking its magneto-motive force.

The relay R4 is so controlled that it is deenergized when the main spring 178 is especially fully wound up, that is, is wound up to a point where contacts 182—183 open, as it would be if the escapement did not quite keep up with the synchronous winding motor SM12 and when deenergized it speeds up the escapement clock for reasons above given. The relay R4 is however also deenergized when the contact 182 is dead by reason of being out of contact with the contact pin 180. This control of the relays R4 and R5 is accomplished by connecting the pin 180 electrically to the gear 181, which in turn is connected by the brush 186 directly to the out-put side of rectifier RI5 and by feeding either the spring contact 182 alone or both of the contact springs 182 and 183 with energy from this rectifier. If the main spring 178 is fully wound the contacts 180—182 are closed with contacts 182 and 183 still in engagement, thus energizing relays R4 and R5, but if the main spring is slightly over-wound because the escapement 172—175 is running slower than the winding motor, that is, is running slower than the cycle passage of the alternating current, the relay R4 drops although the relay R5 remains energized, thereby causing the pendulum to be speeded up. Putting this in different words, after a temporary current cessation both of the relays R4 and R5 are in retracted conditions. When the main spring is fully wound the relays R4 and R5 pick up and by closure of their front contacts 174 and 179 energize the sucking winding 173 thereby reducing from normal the downward pull on the pendulum 172. This causes the pendulum to run abnormally slow and causes winding motor SM12, which was substituted for the winding motor SM13 when the relay R5 picked up, to gain with respect to the escapement 172—175, resulting in the opening of contacts 182—183 and in the deenergization of relay R4. With the relay R4 now deenergized the boosting windings 176—177 are energized thereby causing the escapement to run a little fast resulting in picking up of relay R4. This relay R4 therefore periodically picks up and drops to maintain the escapement in synchronism with synchronous motor driven winding apparatus. The worm wheels 228 and 229 and the worms 230 and 231 have such a gear ratio that the winding shaft 242 operates at exactly 1 R. P. H. when the low speed synchronous motor SM12 operates at synchronous speed from alternating current of regulated frequency and will operate at exactly 3 R. P. H. when the high speed synchronous motor SM13 operates at synchronous speed from the regulated source of alternating current. The gear ratio from main spring gear 181 to the shaft 233 is one to one, because gears 181 and 234 have the same number of teeth and pinions 239 and 239a have the same number of teeth. In other words, when the pendulum 172 operates at correct speed and the winding shaft is rewound by the low speed synchronous motor SM12 the shafts 242 and 233 operate at the same speed of 1 R. P. H. The master clock MC2 also includes a rectifier RI6 for at times applying pulsating current of negative polarity to the secondary clocks.

Operation Fig. 2

Under normal conditions, namely, when alternating current is present and when there has not been a current cessation for some time, the master clock MC2 is fully wound with the relay R5 energized and through its front contact 185 energizing the low speed synchronous winding motor SM12. The relay R4 will, of course, be at times energized and at other times deenergized to cause the escapement mechanism to run an average speed such that the contacts 182—183 remain at the point of barely touching. Between the zero and the fifty-nine minute position of the master clock as reflected by contacts 187—188—189, and by clock hand 190, pulsating current of positive polarity is derived from the regulated alternating current source through rectifier RI5 and is applied to the line wire H2—L2. This current is blocked by the rectifier RI4 but flows freely through the rectifier RI3 and energizes the transformer T13. The secondary winding of this transformer in turn has alternating current of the same frequency (60 cycle) induced therein, which alternating current energizes the synchronous motor SM11. The pulsating current of course returns to the source over the common return wire C2. As explained in connection with Fig. 1 the synchronous motor SM11 through gears 192—195 (see Fig. 1) drives the shaft 142² and the clock hand 191 exactly at the rate of 1 R. P. H. when sixty cycle current of regulated frequency is applied thereto, the gears 157—158—159 preferably having sufficient friction so that they will not be rotated by motor SM11.

At the fifty-nine minute position of the master clock the contact **188** slips off of the cam K^{14} thereby causing contacts **187—188** to open and contacts **187—189** to close. This results in the application of pulsating current of negative polarity to the line wire H^2—L^2. This current upon reaching the secondary clock is blocked by the rectifier RI^3, but flows freely through the rectifier RI^4 and energizes the primary winding of transformer T^{14}. The secondary winding of transformer T^{14} in turn energizes the synchronous motor M^1, or an induction motor, through a circuit including contacts **163—164**. This motor M^1 drives the shaft **142**^{2} and clock hand **191** at substantially sixty times the speed they are driven by synchronous motor SM^{11}, so that the secondary clock may be driven to the sixty minute position where the contacts **163—164** open to stop motor M^1. This occurs during the last minute of the hour as reflected by the master clock MC^2. That is, a clock that is slow to the extent of about fifty-eight minutes may be corrected. Also, a clock that is fast less than one minute will be corrected. At the end of the hour (sixty minute position) of the master clock the contact **187** also slips off of the cam K^{14} as a result of which contacts **187—188** close and contacts **187—189** open, so that the secondary clocks all start from the sixty minute position in synchronism and operate again at the normal rate. It is thus seen that a fast clock will be corrected and that even though a power failure of fifty-eight minutes occurs the secondary clocks will be advanced. Also, it will be noted since both of the windings associated with the permanent magnet PM are deenergized during a current cessation and also during the rewinding operation that the master clock will during this time be adjusted to normal speed adjustment, and therefore will keep very good time. The indicating lamp **197** indicates when the secondary clock S^2 is being corrected.

Fig. 3 structure

The modification of my invention as disclosed in Fig. 3 of the drawings employs a somewhat different principle of operation than Figs. 1 and 2, in that the correction of a slow secondary clock does not take place in the last minute of the hour as is true of the systems shown in Figs. 1 and 2, nor does it take place immediately after a current cessation as is true of the systems shown in my latest filed prior application above mentioned, but takes place intermittently, each correction being smaller than the preceding one until the secondary clock is correct. Also, the master clock may be of a construction similar to that shown in Figs. 1 and 2 where the master clock shaft operates continuously and continuously manifests correct time as distinguished from the type where the master clock has its correcting contacts on the rewind shaft as shown in my above mentioned last filed application.

Referring to Fig. 3 the shaft **200** is preferably a minute shaft, rotating preferably at 1 R. P. H., of one of the master clocks shown in Fig. 1 or 2. This shaft is provided with suitable time indicating means shown conventionally by the minute hand **201**. This shaft **200** is provided with an insulated contact arm **202** rotating therewith and connected, as through the medium of a slip ring **205** and brush **206** to one terminal of a source of alternating current of regulated frequency, the other terminal being connected to a common return wire C^3. To the end of this arm **202** is secured a wipe spring contact **203** which is in contacting relationship with the inside of one of the three twenty minute sectors X, Y and Z of an annulus. These three sectors are insulated from each other as by insulating joints **204** and are so shaped, as shown, that the spring contact **203** snaps from one contact to the other very quickly as the arm **202** rotates at 1 R. P. H.

The secondary clock S^3 is provided with a similar annulus comprising three conducting sectors *x*, *y* and *z*. The sectors X, Y and Z are connected to the sectors *x*, *y* and *z* through the medium of wires **111**, **112** and **113** respectively. It is thus seen that sections X and *x* have a source of alternating current potential connected thereto for the first twenty minutes of an hour. Furthermore, that sectors Y and *y* and Z and *z* have alternating current potential applied thereto during the second and third twenty minute period of each hour, respectively.

The secondary clocks S^3, one having been shown conventionally and one having been shown to illustrate its principle of operation, each comprise a minute shaft **214** (1 R. P. H.) provided with suitable time indicating means, such as, the minute hand **215** (1 R. P. H.) and two contact arms **216** and **217** provided with wipe contact springs **218** and **219**. These contact springs engage the inside of the annulus *x*, *y*, *z*, and are angularly spaced 120 degrees apart so that spring **218** snaps from sector *z* to sector *x* when spring **219** snaps from sector *x* to sector *y*. The arms **216** and **217** are insulated from each other. The arm **216** is connected to slip ring **220**, whereas the arm **217** is electrically connected to slip ring **221**. The slip ring **220** is connected to the low speed motor SM^{14} (1200 R. P. M.) through the medium of brush **222**, whereas the slip ring **221** is connected to the high speed motor SM^{15} (3600 R. P. M.) through the medium of the brush **223**. The other terminal of each of the synchronous motors SM^{14} and SM^{15} is connected to the common return wire C^3. These synchronous motors are energized one at a time as hereinafter explained and through the medium of reduction gearing conventionally shown by the pinion **225** and the gear **226** rotate the minute shaft **214** at one revolution per hour when the synchronous motor SM^{14} is energized and at the rate of three revolutions per hour when the synchronous motor SM^{15} is energized from the regulated source.

Operation Fig. 3

Referring to Fig. 3 it will be noted that alternating current of regulated frequency is successively applied, for twenty minute intervals, by the master clock MC^3 to the stationary segments X, Y, and Z and to wires **211**, **212**, **213** in that order. It is also readily apparent that the secondary clock S^3 is so constructed, if the master clock MC^3 shifts the energy from segment Z to segment X before the secondary clock has shifted its contact spring **218** from stationary segment *z* to stationary segment *x* that the contact spring **219** will still be in contact with the segment *x* and therefore the high speed motor, which may be a synchronous motor or an induction motor but is preferably a two-pole 3600 R. P. M. synchronous motor, will be energized. If the high speed motor SM^{15} has a synchronous speed of 3600 R. P. M. and the low speed motor SM^{14} has a synchronous speed of 1200 R. P. M. then the secondary clock will near the end of every twenty minute period, as defined by the master clock, be advanced to an extent of two-thirds of its tardi-

ness. For instance, should the master clock MC^3 shift alternating current energy from segment Z to segment X when the secondary clock is fifteen minutes tardy and its contact spring **218** assumes the forty-five minute position and the contact spring **219** assumes the five minute position the secondary clock S^3 would run for a period of five minutes at triple speed or in other words would be only five minutes slow instead of fifteen minutes slow when the contact **218** snaps from segment *z* to segment *x*, after which time the secondary clock S^3 again operates at normal speed until the master clock reaches the twenty minute position. In the next twenty minutes as measured off by the master clock MC^3 the five minute tardiness of the secondary clock will be reduced for like reasons, to five-thirds (5/3) minutes or one and two-thirds (1 2/3) minutes. Such corrections will continue at reduced values until the secondary clock has been fully corrected. Also, it will be seen that if a secondary clock S^3 should, for any reason, such as by reason of manual tampering, be fast from one second to nineteen minutes the contacts **218** and **219** would both be in contact with dead or deenergized segments, and therefore the secondary clock would stop until the master clock catches up with the secondary clock, so to speak. In other words, fast clocks that are fast less than twenty minutes when the secondary clock has its contacts shift to new positions will be immediately corrected and slow secondary clocks that are slow less than twenty minutes when the master clock shifts current from one line wire to another will be corrected to the extent of two thirds of its then error in each twenty minute period until it is finally caught up.

Theoretically the secondary clock will never catch up but insofar as practical considerations are concerned it will catch up and be correct in about two hours. For instance, let us assume that a power outage occurs at the forty-five minute position of the master clock and all secondary clocks and that power returns at the end of the sixtieth minute. For reasons above given this fifteen minute tardiness is at twenty minute intervals reduced to the following values: 5, 5/3, 5/9, 5/27, 5/81 and 5/243 minutes. Since 5/243 minutes is equal to one and one-fourth seconds the secondary clocks have, as a practical matter, been corrected within two hours after the termination of the current cessation.

Let us now assume that a current cessation occurs at the one minute position of the master clock and the secondary clocks and that this current cessation continues for thirty minutes, namely, when the master clock is indicating thirty-one minutes past the hour. The master clock MC^3 will, therefore, after the return of power continue to engage the segment Y for a period of nine minutes. During the first six and one-third minutes of these nine minutes the contact **219** of the secondary clock will engage segment *y* as a result of which the secondary clock will operate at triple speed and will assume the twenty minute position when the master clock assumes the thirty-seven and one-third minute position. For the next two and two-third minutes the secondary clock will operate at normal speed and when the master clock reaches the forty minute position and shifts the application of energy from the segment Y to the segment Z the secondary clock S^3 will be slow less than twenty minutes, namely, seventeen and one-third minutes, so that the tardiness of the secondary clock will thereafter be removed for reasons already explained. It is thus seen that under certain favorable time occurrences of current cessations a secondary clock of tardiness greater than twenty minutes or even greater than thirty minutes will be automatically corrected.

Let us now assume that the secondary clock S^3 assumes the fifty-nine minute position when the master clock MC^3 assumes the twenty-one minute position. The master clock contact **203** will therefore engage segment Y, whereas brushes **218** and **219** of the secondary clock engage the segments *z* and *x*, respectively. During the next nineteen minutes of movement of the master clock the secondary clock will of course remain stationary. When now the master clock reaches the forty minute position and shifts energy from the segment Y to the segment Z alternating current can reach the low speed motor SM^{14} of the secondary clock S^3 for a period of one minute after which the brush **218** of the secondary clock S^3 shifts from segment *z* to segment *x*. This operation of the secondary clock again opens the circuit for the slow speed synchronous motor SM^{14}, and since motor SM^{15} is also deenergized the secondary clock S^3 remains in the sixty minute position until the master clock MC^3 also reaches the sixty minute position.

Under certain indicating conditions of the master clock a fast secondary clock, which is fast as much as thirty-eight minutes, will be stopped intermittently until it is in time indicating synchronism with the master clock. In practice it may be difficult to so construct the secondary clock that the contact springs **218** and **219** snap from one segment to another simultaneously for this reason the contacts are preferably so constructed that the spring **218** snaps over a moment earlier than does the contact **219** so that the secondary clock cannot be stopped by reason of the spring **219** having moved off of a particular segment before the spring **218** has moved on such segment. In other words, it is preferable to have both of the motors SM^{14} and SM^{15} energized simultaneously for a moment rather than to have neither of these motors energized which might result in stoppage of the secondary clock for a twenty minute period.

Fig. 4 structure

In Fig. 4 has been shown a modification of the clock system shown in Fig. 3. Since Fig. 3 shows in considerable detail one way how the contacts at both the master clock and the secondary clock may be made snap acting and how the segments with which the rotating brushes make contact may be insulated from each other these features of the present modification will not be specifically shown but will instead be conventionally illustrated. In the system shown in Fig. 3 three control wires and one common return wire are required, whereas in the Fig. 4 construction the line wires have been reduced to two control wires and one common return wire. Also, in the construction of Fig. 3 a tardy secondary clock can be corrected only to the extent of a predetermined fraction of its entire tardiness in each predetermined time period such as twenty minutes, whereas in the construction shown in Fig. 4 similar fractional corrections are made in half-hour periods and a special correction is made in the last minute of

an hour whereby corrections of a tardy clock are made much quicker especially where the tardiness is not in excess of forty-five seconds.

Referring to Fig. 4 the master clock MC^4 may be identical to the master clock MC^3 except for the provision of only two stationary segments A and B instead of three such segments, these two segments suspending substantially equal arcs of 180 degrees, whereas the segments of master clock MC^3 suspend arcs of 120 degrees. As shown this master clock MC^4 also includes a contact arm conventionally shown by an arrow **230** connected to and driven in a clockwise direction by a suitable master clock mechanism such, for instance, as illustrated in Fig. 1 or 2 of the drawings. The master clock shaft **231** (1 R. P. H.) drives suitable time indicating means as conventionally shown by the clock hands **232** and **237** driven thereby. The rotatable contact arm **230** is connected to one terminal of a source of frequency regulated alternating current, as through the medium of a slip ring and brush **235—235a**. This source has been conventionally illustrated by the transformer T^{17} which has its other secondary terminal connected to a common return wire C^4.

The secondary clock S^4, two such clocks having been shown, is of the same general construction as that shown in Fig. 3 but differs therefrom in the provision of two stationary segments instead of three and in having these segments constructed to perform special functions not performed by the system of Fig. 3, and in the further departure in construction whereby the two contact arms conventionally illustrated by arrows **240** and **241** operate in different planes and engage different paths over the stationary segments *a* and *b*, these paths having been shown by dotted lines. The stationary segments A and *a* are connected by a line wire **242** and the stationary segments B and *b* are connected by a line wire **243**. The clock hands **246** and **247** are driven by the minute shaft (1 R. P. H.) **245**, which minute shaft is driven by a synchronous motor SM^{16} or SM^{17}, through the medium of a gear train conventionally shown by the gear **248** and the pinion **249**. The stationary segments *a* and *b* are so shaped and the contact arms **240** and **241** engage these sectors over such paths that the low speed arm **240** engages segment *a* between the fifty-nine minute and thirty minute position of clock S^4 and engages segment *b* between the thirty and the fifty-nine minute position. The high speed arm **241** engages the segment *a* between the thirty minute and the fifty-nine minute position and engages the segment *b* between the fifty-nine minute and the sixty (zero) minute position and also between the one minute position and the thirty minute position of the secondary clock S^4. The low speed arm **240** is connected to the low speed synchronous motor SM^{16} (synchronous speed preferably 1200 R. P. M.) through the medium of slip ring **255** and brush **256**, whereas the high speed arm **241** is connected to the high speed synchronous motor SM^{17} (synchronous speed preferably 3600 R. P. M.) through the medium of slip ring **253** and brush **254**.

Operation Fig. 4

Let us first assume that the secondary clock S^4 is correct and that the master clock MC^4 and the secondary clock both assume the forty-five minute position and that no power failure or current cessation takes place for an hour thereafter. Fourteen minutes later the master clock assumes the fifty-nine minute position and for another minute feeds alternating current of regulated frequency to the segment B, wire **243** and segment *b*. The secondary clock S^4 at this instant (beginning of the sixtieth minute) has its low speed arm **240** enter upon dead segment *a*, but at the same time has its high speed arm **241** enter upon live or energized segment *b*, it formerly having contacted with segment *a*. If desired the contact structure for secondary clock S^4 may be such that there is a slight overlap in contact making, that is, the contact arms **240** and **241** are make-before-break except when the contact arm **241** enters the cut-away portion or insulation **251**. This, the engagement of contact **241** with energized segment *b*, causes the low speed motor SM^{16} to be deenergized and causes the high speed motor SM^{17} to be energized, so that the secondary clock S^4 operates at triple speed and will therefore reach the sixty minute position when the master clock reaches the fifty-nine minute twenty second position. The low speed arm **240** will also have moved upon segment *a* at the fifty-nine minute position of the secondary clock, which segment *a* is still deenergized. When the secondary clock S^4 reaches the zero position the high speed arm **241** will move upon insulation or notch **251**, which will also not supply any current so that both of the synchronous motors SM^{16} and SM^{17} are deenergized and the secondary clock stops. After a wait of forty seconds the master clock MC^4 removes the source of alternating current from segment B to segment A and correspondingly from segment *b* to segment *a*. This causes alternating current to be again applied to the low speed synchronous motor SM^{16}. For the next thirty minutes the secondary clock will remain in exact time synchronism with the master clock at the end of which time the low speed arm **240** will snap from segment *a* to segment *b* simultaneously with snapping of the arm **230** from segment A to segment B. It is apparent that the high speed arm **241** is not in contact with the segment *a* between the zero and thirty minute position and that it is not in engagement with segment *b* between the thirty minute and fifty-nine minute position, so that with the secondary clock running at correct time the high speed motor remains deenergized between the zero minute and the fifty-nine minute position. In other words if a secondary clock is tardy to the extent of forty seconds or less just before the end of the hour the secondary clock will be advanced to indicate correct time to the second at the end of the hour. It is also apparent that a fast clock will be corrected because the contact arm **241** will drop into notch **251** a little earlier and the secondary clock will then be held at stop until the contact arm **230** of the master clock snaps from segment B to segment A.

Let us now assume that at the thirty-two minute position of shafts **231** and **245** and clock hands **232** and **246** a temporary current cessation occurs, and that this current cessation continues for twenty-six minutes. The master clock will, upon resumption of alternating current flow, indicate fifty-eight minutes, whereas the clock hand **246** of the secondary clock will still indicate thirty-two minutes. For a period of two minutes the master clock applies current to segments B and *b*. During these two minutes the secondary clock advances at the normal rate to the thirty-four

minute position. As the contact arm **230** of the master clock MC[4] snaps from the segment B to the segment A current is removed from the low speed synchronous motor SM[16] and is applied to the high speed synchronous motor SM[17]. This will of course cause the secondary clock to operate at triple speed. This will continue for a period of eight minutes and twenty seconds, namely, until the master clock MC[4] has reached the eight minute, twenty second, position and the secondary clock S[4] has reached the fifty-nine minute position. The secondary clock has thus picked up sixteen minutes and forty seconds and is still nine minutes, twenty seconds, slow. With the secondary clock assuming the fifty-nine minute position the high speed contact **241** passes off of the segment *a* and onto the segment *b* and therefore the high speed synchronous motor SM[17] will be deenergized. The low speed arm **240** however at this instant moves from the segment *b* upon the segment *a* as a result of which the low speed synchronous motor SM[16] is energized. The secondary clock S[4] will now operate at normal speed and when the master clock MC[4] assumes the thirty minute position the secondary clock S[4] will assume the twenty minute, forty second position, that is, is still nine minutes, twenty seconds slow. At this instant the master clock MC[4] removes alternating current from the segments A and *a* and applies it to segments B and *b* by snap action contacts such as shown in Fig. 3. This switching of alternating current from segment *a* to segment *b* causes the low speed motor SM[16] to be deenergized and causes the high speed motor SM[17] to be energized, so that the secondary clock again operates at triple speed, but only for a period of one third of nine minutes and twenty seconds, that is, for a period of three minutes and six and two-thirds seconds, at which point in the operation the contact arm **241** of the secondary clock, namely, the thirty minute position of the secondary clock, passes from segment *b* to segment *a* and contact arm **240** passes from segment *a* to segment *b*. The secondary clock will now operate at normal speed and since it has picked up six minutes and thirteen and one-third seconds it is still tardy or late to an extent of three minutes and six and two-thirds seconds. When the master clock reaches the sixty minute (zero) position the secondary clock will reach the fifty-six minute fifty-three and one third second position. The master clock will now shift the alternating current supply from the segment B to the segment A, and of course also from segment *b* to segment *a*. This will cause the low speed motor SM[16] to be deenergized and the high speed motor SM[17] to be energized, but since the insulation at both the top and the bottom between segments *a* and b makes a one minute jog the high speed arm moves upon the segment *b* at the fifty-nine minute position or one-third of two minutes and six and two-thirds seconds (42⅔ seconds) later, at which time the secondary clock has gained one minute and twenty-four and four-ninth seconds and is only one minute and forty-two and two-ninth seconds slow. When the master clock MC[4] reaches the thirty minute position the secondary clock will reach the twenty-eight minute seventeen and seven-ninth second position. Shifting of energy from segment *a* to segment *b* by the master clock will also shift energy from the low speed motor SM[16] to the high speed motor SM[17] and when the master clock reaches the thirty minute thirty-four and 2-twenty-seven second position (thirty minutes plus one third of one minute and 42⅔ seconds) the secondary clock will reach the thirty minute position at which point the contact arms **240** and **241** switch about on the segments *a* and *b* and the secondary clock again operates at normal speed. The secondary clock will have gained one minute $8\frac{1}{27}$ seconds and is still 34 and $\frac{2}{27}$ seconds late. When the master clock reaches the 59 minute 34 and $\frac{2}{27}$ second position the secondary clock reaches the 59 minute position at which point low speed contact arm **240** shifts onto dead segment *a* and high speed contact arm **241** shifts onto the hooked part of live segment *b*, thus operating the secondary clock at triple speed. In the next twenty seconds of operation of the master clock the high speed contact arm **241** will drop into the notch **251** with the secondary clock assuming the sixty minute (zero) position and this occurs at 59 minutes 54 and $\frac{2}{27}$ seconds and before the master clock MC[4] assumes the even hour zero minute position. The secondary clock is now 5 and $25\frac{1}{27}$ seconds fast. The secondary clock will then remain at stop until the master clock reaches the even hour position and again shifts the alternating current from the segment *b* to the segment *a*. In other words, the secondary clock has been fully corrected.

In view of the above discussions of the operating characteristics of the systems shown in Figs. 3 and 4 it is believed helpful to express by formula how a slow clock is corrected in terms of the total tardiness. Let us assume that X is the extent of the tardiness of a secondary clock in minutes, and that each expression on the opposite side of the equation expresses the amount of correction that will be made in that order. For all cases in the Fig. 3 construction where each segment spans an arc of 120 degrees

$$(1)\qquad X=\frac{2}{3}X+\frac{2}{9}X+\frac{2}{27}X+\frac{2}{81}X\ldots\frac{2}{\infty}X$$

where ∞ is infinity. The tardiness X of the secondary clock must of course not be so large that the master clock will energize the segment of the secondary clock in advance of the one engaged by contact spring **219** of the master clock of Fig. 3, for when that occurs the secondary clock will stop until it is slow exactly one hour.

If Fig. 4 were modified to employ segments for the secondary clock such as shown in Fig. 5 then the above formula would apply, but the successive corrections would be made thirty minutes apart instead of twenty minutes apart as is true of the Fig. 3 construction. Referring now to the system shown in Fig. 4 it will be noted that the high speed contact **241** shifts at the bottom (namely at the full hour position) one minute earlier (59 minute position), so that only two thirds of the whole tardiness minus one minute can be corrected at each end of an hour. In view of this difference the above formula must be modified to read for those cases where the current cessation takes place in the second half of an hour as follows:

$$(2)\quad X=\frac{2}{3}[X-1]+\frac{2}{3}\left[\frac{1}{3}(X-1)+1\right]+$$
$$\frac{2}{3}\left[\frac{1}{3}\left(\frac{1}{3}(X-1)+1\right)-1\right]+$$
$$\frac{2}{3}\left[\frac{1}{3}\left(\frac{1}{3}\left[\frac{1}{3}(X-1)+1\right]-1\right)+1\right]+$$
$$\frac{1}{2}[\text{of last correction used}]$$

Simplifying this expression it reads:

$$(2)\quad X=\frac{2}{3}[X-1]+\frac{2}{3}\left[\frac{X}{3}-\frac{1}{3}+1\right]+\frac{2}{3}\left[\frac{X}{9}+\frac{2}{9}-1\right]+\frac{2}{3}\left[\frac{X}{27}-\frac{7}{27}+1\right]+\frac{1}{2}[\text{last correction used}]$$

If we now assume the secondary clock S^4 indicates somewhere in the second half of an hour and is twenty-six minutes slow, the five successive corrections by substituting for X in the above formula will be as follows, where *m* and *s* signify minutes and seconds respectively:

(2) X=16m 40s+6m 13⅓s+1m $24\frac{12}{27}$s+1m $8\frac{12}{81}$s+$34\frac{6}{81}$s=26m.

If we now assume that a current cessation of forty-one minutes takes place at say the thirty-one minute position of the secondary clock then the successive corrections as indicated by the above formula will be as follows:

(2) X=26m 40s+9m 33⅓s+2m 31⅓+1m $30\frac{10}{27}$s . . . $45\frac{5}{27}$s=41m

The above formula (2) is useful if the power failure occurs in the early part of the second half of the hour. For outages that occur shortly after the even hour the following formula must be used:

$$(3)\quad X=\frac{2}{3}[X]+\frac{2}{3}\left[\frac{X}{3}-1\right]+\frac{2}{3}\left[\frac{X}{9}-\frac{1}{3}+1\right]+\frac{2}{3}\left[\frac{X}{27}+\frac{2}{9}-1\right]+\frac{2}{3}\left[\frac{X}{81}-\frac{7}{27}+1\right]+\frac{1}{2}[\text{last correction used}]$$

This may be simplified to read:

$$(3)\quad X=\frac{2}{3}[X]+\frac{2}{3}\left[\frac{X}{3}-1\right]+\frac{2}{3}\left[\frac{X}{9}+\frac{2}{3}\right]+\frac{2}{3}\left[\frac{X}{27}-\frac{7}{9}\right]+\frac{2}{3}\left[\frac{X}{81}+\frac{20}{27}\right]+\frac{1}{2}[\text{last correction used}]$$

If we now assume that a current cessation occurs at say three minutes after the hour and continues for twenty-six minutes the several corrections as determined by this formula are as follows:

(3) X=17m 20s+5m 6⅔s+2m $22\frac{6}{27}$s+$7\frac{11}{27}$s+$42\frac{38}{81}$s+$21\frac{19}{81}$s=26m

Let us now assume that a current cessation occurs in the early part of the first half of an hour and continues for six minutes, the successive corrections will then be as follows:

(3) X=4m+40s+53⅓s . . . +26⅔s=6m

It will be noted that the fourth and fifth expressions were not used. The reason for this is that the special end-of-hour correcting means by the application of current to the high speed motor SM^{17} during the fifty-ninth minute of the hour is capable of making a maximum correction of forty seconds. This is true because if the master clock is at 59m 40s it can advance the secondary clock S^4 forty seconds during the remaining twenty seconds in the fifty-ninth minute. In other words, if the advance in any odd advancing period is less than eighty seconds all the remaining expressions except the last in Formula 3 will be omitted. The same is true of Formula 2 as to even instead of odd advancing periods. If we now assume a current cessation of two minutes occurs in the first half of an hour, using Formula 3, the advances made by the secondary clock will be: 1m 20s and 40s=2m.

It should be understood that each of the three above mentioned formulae assume synchronous clock motors wherein the speed of the high speed motor is three times that of the low speed motor. If now there is a larger speed ratio the secondary clocks will be advanced much faster. For instance, if we assume a two pole high speed synchronous motor and a 12 pole low speed synchronous motor the numerical expressions in the above formulae will be correspondingly changed and Formula 3 will read as follows:

$$(3^a)\quad X=\frac{5}{6}[X]+\frac{5}{6}\left[\frac{X}{6}-1\right]+\frac{5}{6}\left[\frac{X}{36}-\frac{1}{6}+1\right]\text{ etc. . . . }+\frac{1}{5}[\text{last correction used}]$$

If we now, with a speed ratio of six to one, assume that a current cessation takes place in the early part of the first half of an hour and that this cessation continues for ten minutes, and we substitute in the last above mentioned formula the successive corrections will be as follows:

(3^a) X=8m 20s+33⅓s+55⅝s . . . +11⅛s=10m

If we now assume a current cessation of twenty-eight minutes at the thirty-two minute position of a secondary clock having motors of a speed ratio of 8 to 1 Formula 2 will become:

$$(2^a)\quad X=\frac{7}{8}[X-1]+\frac{7}{8}\left[\frac{X}{8}+\frac{7}{8}\right]\text{etc. . . . }\frac{1}{7}$$

last expression used]

and substituting 28 for X we have:

(2^a)

X=23m 37½s+3m $49\frac{11}{16}$s . . . $32\frac{13}{16}$s=28m

In other words the secondary clock will only be tardy $32\frac{13}{16}$ seconds an hour after the current cessation started, that is, a half hour after the current cessation terminated, and will be fully corrected one hour after the current cessation terminated.

If a current cessation takes place at such a time that the first correction in the formula cannot be made then the correction that is actually made by the structure of Fig. 4 will be subtracted from the total tardiness and then the proper formula will be used for the remainder. For instance, let us assume that with the Fig. 4 construction a current cessation of fifteen minutes is started at the twenty-seven minute position of the master and secondary clock. When power comes on the secondary clock will advance two minutes during the first minute that current is available. The remaining error will be thirteen minutes and by substituting 13 in Formula 2 since the secondary clock is now operating in the second half of the hour it is readily found out what the advances of the secondary clock after the first advance of two minutes will be.

It should be remembered that a fast clock can also be corrected and that is true irrespective of whether it was first fast in the first or the second half of an hour. It has been pointed out above how when a secondary clock S^4 of Fig. 4 is fast during the second half of an hour may be corrected. Let us now assume that clock S^4 is fast two minutes during the first half of an hour. At the twenty-eight minute position of the master clock MC^4 the secondary clock S^4 shifts from the low speed motor to the high speed motor and during the next two minutes

of actual time the secondary clock becomes four more minutes fast, so that it is now six minutes fast. Also at the fifty-nine minute position of the secondary clock it again shifts from the low speed motor to the high speed motor and during the next twenty seconds it gains forty seconds and then contact **240** remains in the zero minute position on dead segment *a* with contact **241** in notch **251** until the master clock has also reached the zero minute position.

Fig. 6 structure

In the system shown in Fig. 6 the master clock is identical to the one shown in Fig. 2 except that alternating current is applied to the two control line wires **248** and **249** alternately in half hour intervals by the contact arm **250**, as also shown in Fig. 4, and except for the further modification including back contact **259** of relay R^5 which connects the two control line wires **248** and **249** together during high speed rewinding operation of the master clock as manifested by deenergization of the relay R^5. Furthermore, the secondary clock employed in the system of Fig. 6 is identical to the secondary clock of Fig. 4, for which reason like parts of Fig. 6 also shown in Fig. 2 or 4 will be assigned like reference characters as already used in Figs. 2 and 4. In the structure of Fig. 6 alternating current is derived from a source of regulated frequency, preferably sixty cycle, which has been conventionally illustrated by the transformer T^{18}.

Operation Fig. 6

Stating it very briefly, the system illustrated in Fig. 6 functions precisely the same as the system shown in Fig. 4 except that both control line wires are energized whenever the master clock is being wound at a high speed rate, as it will be when the relay R^5 is in its deenergized condition while alternating current is available, that is, after each current cessation and for a time proportional to the duration of such cessation. The synchronous motors SM^{16} and SM^{17} of Fig. 6 have such relative torque that the high speed motor SM^{17} dominates when both motors are energized. In other words, the secondary clock S^6 operates at triple speed while both of its motors are energized, operates at triple speed when the motor SM^{17} only is energized and operates at normal speed if only the low speed motor SM^{16} is energized. It is thus seen that after a current cessation the secondary clock will operate at triple speed so long as alternating current is available and the relay R^5 is deenergized, and this is for a period equal to half of the time of the current cessation since the high speed winding motor SM^{13} of Fig. 2 operates at triple the speed of winding motor SM^{12} or the winding operation catches up, so to speak, at double speed. In other words, since the high speed and low speed motors SM^{17} and SM^{16} of Fig. 6 have synchronous speeds like the high speed and low speed winding motors SM^{13} and SM^{12} of Fig. 2 the shaft **245** of the secondary clock of Fig. 6 operates substantially in synchronism with the winding shaft **242** of the master clock of Fig. 6 (see also Fig. 2).

Let us now assume that a current cessation takes place at the zero minute position of the master clock MC^6 and the secondary clock S^6 and that this current cessation continues for fifty-five minutes. The master clock will therefore assume the fifty-five minute position whereas the secondary clock assumes the zero minute position upon the termination of the current cessation. During this current cessation the master clock SM^6 continues to operate and keeps substantially correct time with both the coils **173** and **176—177** deenergized and with both of the winding motors SM^{12} and SM^{13} (see Fig. 2) deenergized. As soon as the current cessation terminates the high speed rewind motor SM^{13} is energized and operates at synchronous speed, it being energized through back contact **185** of relay R^5, the relay R^5 being deenergized because contacts **180** and **182** are not in contact with each other. Also with relay R^5 deenergized its back contact **259** connects (see Fig. 6) line wires **248 249** together as a result of which both of the contact segments *a* and *b* of the secondary clock S^6 have potential applied thereto. During the first minute of the return of current on the alternating current system the low speed synchronous motor SM^{16} only of the secondary clock S^6 will be energized. This is true because the contact arm **241** will be in the notch **251** during the first minute of operation as manifested by the secondary clock S^6 and this secondary clock will operate at normal speed. The rewinding operation of the master clock will take place at triple speed so that the rewind shaft **242** is only fifty-three minutes tardy, whereas the secondary clock S^6 is still fifty-five minutes tardy. During the next twenty-six and one-half minutes of operation of the master clock MC^6 the contact **182** of this master clock will have caught up with the pin **180** because it gains two minutes for every minute of operation when the high speed rewind motor SM^{13} (see Fig. 2) is energized. During the next nineteen and two-thirds minutes of operation as measured by the master clock MC^6 the secondary clock S^6 runs at triple speed and gains two minutes for each minute of operation so that it has gained thirty-nine and one-third minutes when its shaft **245** has operated through an arc of fifty-nine minutes and again indicates the sixty minute (zero) position. The secondary clock is now only fifteen and two-thirds minutes tardy. During the next minute of operation of the master clock MC^6 the secondary clock S^6 does not gain with respect to the master clock MC^6, because only the low speed synchronous motor SM^{16} is energized the contact arm **241** again being in the notch **251**. The fifty-five minute tardiness of the rewind shaft **242** (see Fig. 2) has now been corrected to the extent of forty-three and one third minutes and is still tardy to the extent of eleven and two-thirds minutes. During the next five and five-sixths minutes of operation of the master clock MC^6 the main spring **178** is fully wound up and the relay R^5 is energized and the shunt is removed from the line wires **248—249** by the opening of back contact **259**. Also during this five and five-sixths minutes of operation of the master clock MC^6 the secondary clock S^6 gains twice this amount making a gain of eleven and two-thirds minutes or a total gain of fifty-one minutes. The secondary clock S^6 is therefore only four minutes late or tardy at this time, namely, when the master clock MC^6 assumes the twenty-two and one-half minute position and the secondary clock S^6 assumes the eighteen and one-half minute position. These four minutes of tardiness of the secondary clock S^6 will now be corrected in precisely the same manner as was described in connection with the system shown in Fig. 4. It is readily seen from the foregoing discussion that had the assumed power failure

of fifty-five minutes occurred one minute later the secondary clock would only have been tardy two minutes instead of four minutes when the master clock was fully rewound, because the secondary clock would have had its contact arm **241** pass over the notch **251** only once during the rewinding operation of the master clock MC^6. It should also be understood that the feature of connecting together the line wires, such as wires **248** and **249** by contact **259**, during the rewinding operation may also be employed when the contact making structure such as shown in Fig. 5 of the drawings is used.

Reviewing the structure of Figs. 3, 4, 5, 6 and 12, the systems shown therein employ the principle of correspondence and non-correspondence. When a secondary clock is tardy or late the low speed motor is not switched to a new circuit as early as energy is applied to such new circuit by the master clock and non-correspondence exists.

Fig. 12 construction and operation

Instead of employing a back contact **259** of the relay R^5 of Fig. 6 for connecting the control line wires **248** and **249** together pole changer contacts **330** and **331** may be employed to switch the two wires **248** and **249** about. This effect is the same as umpiring that the secondary clock is thirty minutes late when as a matter of fact it is on time insofar as its agreement with the rewind shaft **242** of the master clock is concerned. It should be noted that Fig. 12 also differs from Fig. 6 by having contact arm **250** mounted on the rewind shaft **242** instead of on the main minute shaft **233**. Let us, for instance, assume that at the ten minute position of the master clock and the secondary clock a current cessation of fifteen minutes takes place with the Fig. 6 construction modified as illustrated in Fig. 12. Upon termination of the current cessation, the relay R^5 will remain deenergized for reasons explained in connection with the master clock construction of Fig. 2. The contact arm **250** of Fig. 12 and the contact arm **240** of its secondary clock (not shown but see Fig. 6) will both assume the ten minute position. With the contacts **330** and **331** of the relay R^5 in their retracted position the segments A and *b* will be connected together, as a result of which the synchronous motor SM^{17} will receive energy from segment *b* through the medium of contact arm **241**. For the next seven and one-half minutes of actual time the rewind motor SM^{13} (see Fig. 2) and the synchronous motor SM^{17} (see Fig. 6) will be energized, the relay R^5 being deenergized. At the end of this seven and one-half minute period the relay R^5 picks up and the low speed rewind motor SM^{12} is substituted for the high speed rewind motor SM^{13} and the segment A and B are reconnected to segments *a* and *b* respectively, as a result of which the secondary clock, since it operated at triple speed for a period of seven and one-half minutes, has fully caught up and now again indicates substantially correct time. If a secondary clock should be slightly in error it will be corrected at the end of the hour as explained in connection with the Fig. 4 system. If desired however the contact arm **250** of the Fig. 12 system may be driven by the shaft **233** instead of the rewind shaft **242**. In the Fig. 12 construction therefore correspondence between contacts **250** and **240** has artificially been changed to non-correspondence so that insofar as circuits are concerned non-correspondence exists, so that the high speed motor, unless its contact arm is in the notch or dead position **251**, will be connected in the circuit to which energy has been supplied and the secondary clock will gain so long as the contacts of the secondary clock remain out of correspondence with the master clock contacts.

Fig. 7 construction and operation

In Fig. 7 has been illustrated how a continuously operated one revolution per minute shaft movement of any one of the secondary clocks of Figs. 1, 2, 3, 4, 5 and 6 may be converted into an intermittently operated one revolution per hour shaft movement. Such an intermittently driven minute 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 **30**. In the construction shown the shaft **31** is operated by the synchronous motors of one of the secondary clocks shown in Fig. 1, 2, 3, 4, 5 or 6 in a clockwise direction and at a speed of one revolution per minute. The arm **32** pivoted at **33** and having a lug 32^1 has its lug engage the cam **34** keyed or otherwise fastened to the shaft **31**. This arm **32** has pivoted thereto a pawl **35** so shaped that it will engage the teeth of the ratchet wheel **36** and when it has operated this ratchet wheel **36** an arc equal to one ratchet tooth this pawl will bind under the pin **37**, so as to avoid overthrow. That is, to avoid the ratchet wheel **36** being turned more than one tooth one-sixtieth of a revolution for each rotation of the shaft **31**. The arm **32** is biased to the right by a spring **38** and the pawl **35** is biased down by the spring **39**. The holding pawl **40** is pivoted to a stationary support by a pivot **41** and is urged in engagement with the ratchet wheel **36** by a spring **42**. From the construction illustrated in Fig. 7 it is readily seen that during the major part of each revolution of the shaft **31** the arm **32** is gradually moved toward the left and that at the end of each minute, or other suitable interval, the lug 32^1 slips off of the cam **34** thereby causing the ratchet wheel **36** to be advanced in a clockwise direction six degrees, or an amount equal to one minute. This wheel **36** operates the type wheel **30**, and for each operation of the pawl **35** 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.

Referring for a moment to the rotatable mechanism housings G^1 and G^2 shown in Figs. 1 and 2 instead of having the rotor **196** on a shaft **141** projecting from the housing and having it driven by a stationary stator SM^{10} or SM^{11} the stator may also be located entirely within the housing and rotated therewith when the housing is rotated. In this case slip rings engaged by stationary brushes are preferably connected to and insulated from this housing. This latter construction would permit a smaller air gap to be used and would permit the rotor **196** to be contained within the oil contained housing G^1 or G^2.

Motor structure

In Figs. 8 and 9 have been illustrated one form and in Figs. 10 and 11 have been illustrated another form of double motor, including each a low speed stator and rotor and a high speed stator and rotor, wherein both rotors are secured

to the same shaft or sleeve and supported by the same bearing structure.

Structure and operation Figs. 8 and 9

Fig. 8 shows the preferred form of double motor in cross-section and Fig. 9 shows an exploded isometric view of the same motor. In this double motor the two pole rotor **260**, which is preferably made of soft iron or steel, is press mounted on the same sleeve **261** with the six pole rotor **262** made of the same material as the rotor **260**. Each of these rotors **260** and **262** has associated therewith a hysteresis cup **264** of very thin sheet steel having an outside diameter equal to the outside diameter of its associated rotor armature **260** or **262**. These steel cups are made of permanent magnet steel or other permanent magnetic material and are primarily used to produce starting torque when a cup is at rest or is rotating at less than synchronous speed. The two rotors **260—264** and **262—264** are held apart on the sleeve by a second sleeve **265**. The sleeve **261** has gear teeth **300** cut therein near one end for driving a gear train including the gear **267**. The sleeve **261** is mounted for rotation on the spindle **268** fixedly secured in the housing including end plates **269** and a circular box **270**.

The double stator comprises disks **271**, **272**, **273** and **274** of soft iron and disks **275**, **276**, **277**, **278** and **279** of copper or other conducting material of low resistance. Of these disks the disks **274** and **279** are provided with a rather small central opening, the copper disks **276**, **277** and **278** are provided with a slightly larger central opening and the iron disks **272** and **273** are provided with still larger central openings. The central openings in the copper disks **276**, **277** and **278** are made smaller than the central openings in iron disks **272** and **273** in order to more efficaciously screening the iron disks **272** and **273** from each other and from the rotors **260—264** and **262—264**. Between the disks **275** and **276**, and around the outside of the pole pieces **283**, **284**, **285**, **287**, **288**, **289**, **294** and **295** thereof, is mounted the low speed coil **280** and between the disks **278** and **279**, and around the pole pieces **296**, **297**, **298** and **299** thereof, is mounted the high speed coil **281**. The casing **270** is constructed of iron and constitutes, at certain points, the magnetic circuit for each of the two motors. That is, the low speed coil **280** surrounds the three poles or pole pieces **283**, **284** and **285**, conveniently called north poles, and their associated shaded poles **287**, **288** and **289** respectively. These six pole pieces are securely fastened in the iron plate or disk **271**. The copper disk **275** is provided with holes into which these pole pieces fit snugly so as to furnish a low resistance path for eddy currents flowing around the shaded pole pieces **287**, **288** and **289**. It will be noted that eddy currents cannot flow in disk **275** around pole pieces **283**, **284** or **285** by reason of the slots **290**, **291** and **292** cut into disk **275**. Into iron disk or plate **272** are secured six similar pole pieces, which are conveniently called south poles, which are similarly alternately shaded and unshaded and each pair of these pole pieces are also contained within the low speed coil **280** and are located between the pairs of north poles in plate **275**. Only one shaded pole **294** and one unshaded pole **295** of these six poles have been illustrated and these two south poles **294** and **295** are located between the north poles **285** and **287**. The shaded south pole **295** is shaded by the copper disk **276**. It is readily seen that energization of the low speed winding will result in magneto-motive forces in the twelve poles lying axially in the opening thereof, but this will result in very little magnetic flux passing directly endwise through these pole pieces from one iron plate **271** to the other iron plate **272**. This is true because the copper plate **276** shields the iron plate **272** magnetically from the pole pieces **283**, **284**, **285**, **287**, **288** and **289** and similarly shading is afforded by the copper plate **275** between the iron plate **271** and the six south poles including pole pieces **294** and **295**. The net result is that a six pole motor has been constructed in which the magnetic pole shoes are fed magnetically from the ends thereof instead of radially as in the more common construction. The magneto-motive forces thus cause magnetic fluxes to pass first from the unshaded north poles to the unshaded south poles and then from the shaded north poles to the shaded south poles, and these fluxes find the path of least reluctance to be through the rotor **262—264**. These successive fluxes alternating in polarity and shifting in position produced by alternating current passing through the winding **280** results in a rotating magnetic field which tends to drag the steel cup **264**, associated with the six lobe disk **262** with it substantially up to a speed of synchronism, at which point the lobes or points of this disk **262**, which may be constructed of soft iron or steel, fall into step with the magnetism and rotate in synchronism with this magnetic field. Since there are three pairs of unshaded poles the rotor will run at twelve hundred R. P. M. with sixty cycle applied to the winding **280**.

The high speed portion of this double motor is of the same general construction as the low speed portion, it differing therefrom by having only one pair of unshaded pole pieces **296** and **297** and one pair of shaded pole pieces **298** and **299** and by having a two pole rotor **260** instead of a six pole rotor. The pinion **300** is therefore rotated at 1200 R. P. M. or 3600 R. P. M. depending on whether the winding **280** or **281** is energized by alternating current of sixty cycle frequency. Since the high speed synchronous motor **260—281** is used for the purpose of allowing a tardy secondary clock (see my prior application Ser. No. 239,538) to catch up suitable contact means controlled by the secondary clock is preferably employed. And although this contact means may be of the construction shown in Figs. 3, 4 and 6 the contacts **301** controlled by the insulating cam **302** driven by gear **267** has been illustrated. These contacts **301** open the circuit at predetermined chronological conditions of the secondary clock so that the clock will stop until the low speed motor winding **280** is energized. A single motor of the construction shown in Fig. 8 is preferably used within the gear housing G^1 or G^2 (Figs. 1 and 2) when it is desired to use a motor mounted wholly within such gear housing as pointed out hereinbefore, in which event slip rings and brushes will be used to energize such motor for any position the gear housing may then be assuming.

In Figs. 10 and 11 have been illustrated another form of double synchronous motor also designed to operate at 1200 or 3600 R. P. M. depending on which of its two windings is energized, and having both of its rotors secured to the same shaft **311**. From the clock gear housing **310** is projecting the shaft **311** to which are secured the rotors **312** and **313**. The two pole rotor **312** is preferably of a construction the same as that of the rotor of synchronous motors SM^{10}, SM^{11}, SM^{13}, SM^{15} and SM^{17}, which comprises a very thin

disk of tempered steel punching, the punching having holes punched therein to leave two spokes and a rim, the spokes being 180° apart. This construction results in low reluctance through the rotors in one direction and comparatively high reluctance at a right angle to such direction through the plane of the disk. When this rotor reaches its synchronous speed the steel disk becomes a permanent magnet having its flux divided between the end-to-end spoke and the two substantially parallel rim portions, and this permanent magnet locks itself into the rotating magnetic field and therefore runs in synchronism with the rotating field. The high speed stator **314** has only been shown in Fig. 11 but is of a construction such as the stators of the synchronous motors SM^{10}, SM^{11}, SM^{13}, SM^{15} and SM^{17} except that the shaded pole of one polarity is substantially in contact with the unshaded pole of the opposite polarity. This latter construction produces a heavier lagging flux in the shaded poles. These rotors **312** and **313** have been omitted from Fig. 10 in order to more clearly show the six pole low speed stator **315**.

The six pole rotor **313** is punch-and-die formed in a shape such as illustrated in cross-section in Fig. 11 and is constructed of tempered steel having high permanence so that when magnetized it acts like a permanent magnet. This permanence is, however, not so high that it cannot be re-magnetized by the stator, this in order to make it act like a hysteresis disk to afford starting torque when the rotor is started from rest. It will be noted that the shape of the rotor is such as to afford an external cylindrical surface lying within the projecting stator poles of the stator **315** and to afford an internal cylindrical surface to cooperate with the outside surfaces of these stator poles.

This stator **315** comprises a central, preferably laminated, core **315a** to one end of which is secured a soft iron spider **316** and to the other end of which is secured a soft iron spider **317**. These spiders **316** and **317** have their projecting poles bent at right angles to the plane of such spider, as illustrated, so as to all lie in the same cylindrical plane of a diameter to fall midway between the two cylindrical planes of the rotor **313**. The poles are held in position by a ring **320** of copper, or other metal of low electrical conductance, having twelve rectangularly shaped holes therein. Alternate ones of these holes are slotted as shown by the slots **321**. The slots are provided so as to render the poles passing through the holes to which these slots are cut non-shaded. It is thus seen that if we, for convenience, call the right-hand end of core **315a** a north pole and the left-hand end a south pole that each of the iron poles projecting from spider **316** are north poles and the poles projecting from spider **317** are south poles. It is also apparent from Fig. 10 that alternate north poles are shaded and the remaining ones are unshaded and that that is also true of the south poles projecting from spider **317**. Also that shaded north poles lie closer to unshaded south poles than do shaded south poles. This latter construction is resorted to in order to increase the lagging flux emitted from the shaded poles especially during the latter part of each magnetic flux wave. The north and south poles heretofore mentioned are produced by energization of the winding **325** surrounding this core **315a**. This winding is in practice energized by alternating current preferably of sixty cycle frequency and when so energized will produce a rotating magnetic field in the rotor **313** rotating at 1200 R. P. M. In order not to rely on the residual magnetism of the rotor **313** alone for obtaining synchronous speed operation radial slots are cut into this rotor **313** substantially as shown for the rotors of synchronous motors SM^{12}, SM^{14} and SM^{16}. It is thus apparent that if the winding **325** of the stator **315** is energized by alternating current of sixty cycle frequency the shaft **311** will be driven at 1200 R. P. M., whereas if the winding of the stator **314** is energized by such alternating current the shaft **311** is rotated at 3600 R. P. M. It is, of course, understood that the stator **314** includes shading coils such as illustrated for the synchronous motors SM^{10}, SM^{11}, SM^{13}, SM^{15} and SM^{17} and that the stator will be so placed on the rotor that both of the rotors **312** and **313** will rotate in the same direction.

Fig. 13 construction and operation

In Fig. 13 has been illustrated a two circuit two speed single stator single rotor synchronous motor $2SM^{19}$ that may be substituted for any one of the double units SM^{12}—SM^{13} (Figs. 2, 6 and 12); SM^{14}—SM^{15}, SM^{16}—SM^{17} (Figs. 3, 4, 6 and 12).

This two-speed synchronous motor $2SM^{19}$ comprises two generally U-shaped stator cores **340** and **341** constructed of soft iron laminations. One pole, namely, the rearward pole with respect to the direction of rotation, of each of these U-shaped cores **340** and **341** is bifurcated and provided with a shading coil **342** to cause such direction of rotation. The ends of the poles of these U-shaped cores **340** and **341** are rounded to leave a small uniform air-gap between them and the tempered steel rotor **345** and are so spaced as to constitute a four pole construction in which alternate poles are shaded for the same direction of rotation and so that the shaded portion of a shaded pole lies adjacent the other pole of the same core **340** or **341**.

If now these cores are so excited from a source of alternating current that adjacent poles of different cores have like instantaneous magnetic polarities we have a typical two-pole motor stator of which each pole belongs half to one core **340** and half to the other core **341** and which two poles each has a single shading coil to produce clock-wise rotation of a magnetic field. This two-pole magnetic field rotating in a clockwise direction produces hysteresis torque in the rotor **345** tending to drag this rotor with it. As the rotor approaches its synchronous speed of 3600 R. P. M. the rotor due to the path across it of low reluctance and including the two spokes in series, having in multiple therewith two rim portions, locks in with this magnetic field, so that the rotor operates at 3600 R. P. M., assuming a sixty cycle alternating current source.

If now the stator cores **340** and **341** are so magnetically excited from such a source of alternating current that adjacent poles of different cores have opposite instantaneous magnetic polarities we have a four-pole stator of which two adjacent poles belong to one core member **340** and the other two poles belong to the other core member **341**. This four-pole magnetized structure has alternate poles only shaded, that is, has either the north poles or the south poles shaded for clockwise rotation for a particular magnetic wave of a magnetic cycle. This four-pole magnetic field will of course rotate only at a speed of 1800 R. P. M. and will tend to drag the rotor **345** with it. When the rotor **345** approaches synchronous

speed it will lock in, so to speak, with this rotating magnetic field. This locking-in effect is produced by the four slots **346** cut radially into the rotor **345** from the outside and causes the rotor to operate at 1800 R. P. M.

In order to increase the amount of alternating current flowing in the shading rings **342** and correspondingly increase the lagging magnetic flux produced thereby the pole pieces are provided with extensions of magnetic material **340a** and **341a**. By looking at the stator structure of Fig. 13 it will be seen that if the stator is magnetized to produce a two-pole magnetic field the usual shading is afforded but that when the stator is magnetized to produce a four-pole magnetic field only two of the four poles are provided with shading coils. This has been done purposely, because if the other two poles had been bifurcated and shading rings had been provided these additional shading rings would have produced harmful effects when the magnetic structure is excited to produce a two-pole magnetic field, in that such additional shading rings would lie in the middle of the unshaded portion of each of the two poles.

In order to produce two-pole or four-pole magnetization of the core structures **340—341** the core **340** is preferably provided with a plane helical coil **347** and the core **341** is provided with a helical coil **348—349** having a center tap **350**. This center tap is preferably connected to one terminal of the coil **347** the other terminal of this coil **347** being connected to the "common" wire in the particular system in which the motor $2SM^{19}$ is used. Each of the coils **347, 348** and **349** preferably has the same number of turns so that the magneto-motive force from pole to pole of the two cores **340** and **341** is the same irrespective of which of the two circuits is energized. It is thus seen that if alternating current is caused to flow from the wire "low" to the wire "common" four-pole magnetization will result causing the rotor to operate at 1800 R. P. M., but if alternating current is caused to flow from the wire "high" to the wire "common" two pole magnetization results, the magnetic polarities for four-pole magnetization and for two-pole magnetization of the core **341** having been illustrated by the solid letters N and S and the dotted letters N and S, respectively. Under normal conditions the motor $2SM^{19}$ will be energized to constitute a four-pole motor, but it will be energized to constitute a two-pole motor when a secondary clock is to be advanced or a main spring is to be wound up at double speed.

If the motor $2SM^{19}$ is substituted for the winding motors SM^{12} and SM^{13} the wire "low" will be connected to front contact **185** of relay R^5, whereas the wire "high" will be connected to back contact **185** of this relay. The gear ratio of the winding gears will remain the same but the time required for the rewinding to catch up will be increased. When this master clock of Fig. 2 is employed as a master clock for the systems of Figs. 6 and 12 it is also essential that a similar motor be used for each of the secondary clocks used in the system. In other words, the ratio of high speed to low speed ratio for the secondary clocks should be the same as high speed to low speed ratio of the rewind apparatus of the master clock for such system.

When the motor $2SM^{19}$ is substituted for the two motors in any one of the secondary clocks the wire that formerly lead to the low speed motor will be connected to the lead-in wire "low" and the wire that was formerly connected to the high speed motor will be connected to the lead-in wire marked "high." This motor $2SM^{19}$ will obviously not be used in the secondary clocks of Figs. 1 and 2.

If this motor is used in the systems of Fig. 3, 4, 6 or 12 instead of the two synchronous motors the corrections of a tardy secondary clock will be made slower in proportion to the ratio of speeds high to low. Since the motor $2SM^{19}$ has a high-to-low speed ratio of 2 and the synchronous motors SM^{17} and SM^{16} has a high-to-low speed ratio of 3 it will take approximately fifty percent more time to correct a tardy clock if the motor $2SM^{19}$ is substituted, and Formulae 2 and 3 above will have to be correspondingly changed. Also, if desired, the poles **296** and **298** of Figs. 8 and 9 may be secured to iron plate **272** in which event plates **273** and **277** may be omitted.

It should be understood that when the two speed synchronous motor $2SM^{19}$ is substituted for the two synchronous motors SM^{16} and SM^{17} of Fig. 6 that the secondary clock S^6 will run double normal speed when both of the line wires **248** and **249** are energized. This by reason of the fact that the currents flowing in coils **348** and **349** will be neutralized and that the current flowing in the coil **247** will be materially increased by reason of reduced resistance due to coils **348** and **349** being in multiple, so that a two-pole magnetic field will be produced in which the poles are almost displaced 180 degrees causing the rotor to operate at two pole synchronous speed. If on the other hand, this two speed synchronous motor $2SM^{19}$ is used in the system of Fig. 12 there is a possibility that during a secondary clock correction after a power failure the contact arm **241** will lodge in the notch **251** and thereby hold the secondary clock at stop. In order to prevent this, contacts **352—353** controlled by the rewind shaft **242** and closed between the 59½ and the 2½ minute positions of this shaft connected in series with a back contact **353** of relay R^5 may be employed to apply current to the wire **248** as a result of which current is applied to the four-pole circuit of this motor $2SM^{19}$ during the first minute of an hour as manifested by the secondary clock and resulting in the operation of this motor at normal speed and movement of the contact arm **241** out of the notch **251**, all as shown in Fig. 12 of the drawings. Thereafter the secondary clock will again operate at double speed until the relay R^5 picks up.

Referring to the drawings it should be understood that the various inventions and the various forms illustrating the same general invention have been shown specifically in some instances for the purpose of explaining their principles of operation and not with any attempt of limiting them to this particular construction. Referring to Figs. 1 and 2, for instance, the two embodiments of master clocks illustrated therein, although they have been illustrated as master clocks and are particularly applicable to perform a master-clock function it should be understood that they may be used as a mantle clock of the sustained power type. In Fig. 1 the condenser N is used to dampen out the direct current ripples produced by the rectifier RI^2, so that the direct current flowing in the coil **155** is substantially continuous. In each form of the invention illustrating a clock system two secondary clocks have been illustrated. One of these secondary clocks shows its outside appearance whereas the other shows conventionally its internal construction. The double motors shown

in Figs. 8 and 11 and the two speed motor of Fig. 13 may be used in any one of the secondary clocks S^3, S^4 or S^6 or may be used in place of the rewind motors SM^{12} and SM^{13} of Fig. 2. Having thus shown and described a number of embodiments of the present invention it is desired to be understood that the invention is not limited to these particular constructions except as demanded by the scope of the following claims.

What I claim as new is:

1. In an electric 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 in combination a mechanical time measuring means and a synchronous motor for accurately manifesting the passing of time so long as no current cessation occurs and for substantially accurately manifesting the passing of time during a current cessation, a secondary clock including a low speed synchronous motor and a high speed synchronous motor, said low speed synchronous motor when energized from said source operating said secondary clock to correctly manifest the passing of time and said high speed synchronous motor when energized from said source operating said secondary clock at a faster rate, line circuits connecting said master clock and said secondary clock, contacts controlled by said master clock for energizing said circuits in succession from said source, and means including contacts controlled by said secondary clock for connecting said synchronous motors to said line circuits in succession in the same order in accordance with the lapse of time as manifested by said secondary clock and in a manner so that both synchronous motors are not simultaneously connected in the same line circuit and so that the low speed motor is connected into that line circuit into which the high speed motor was last connected, whereby if the contacts controlled by said master clock are operated to shift the source of alternating current from one circuit to another before the contacts of the secondary clock have operated said high speed synchronous motor is energized.

2. In an electric clock system, the combination with a source of alternating current having its frequency regulated to correctly manifest the passing of time, a master clock of the sustained power type having a time shaft that operates in perfect sub-synchronism with the alternating current from said source so long as no current cessation occurs and which operates at substantially the same speed during a current cessation, a secondary clock having a low speed synchronous motor and a high speed synchronous motor, said low speed motor when energized from said source operating said secondary clock to correctly manifest the passing of time and said high speed motor when energized operating said secondary clock at a higher speed, two line circuits connecting said master clock and said secondary clock, contacts controlled by said master clock for energizing said circuits alternately at time intervals as measured by said master clock, means including contacts operated by said secondary clock for alternately connecting said low speed motor to one and then the other of said circuits at corresponding time intervals as measured by said secondary clock and for at times connecting said high speed motor to that line circuit to which said low speed motor is not connected, whereby if said secondary clock is tardy it is at times operated at increased speed by said high speed motor.

3. In an electric clock system, the combination with a source of alternating current having its frequency regulated to correctly manifest the passing of time, a master clock of the sustained power type having a time shaft that operates in perfect sub-synchronism with the alternating current from said source so long as no current cessation occurs and which operates at substantially the same sped during a current cessation, a secondary clock having a low speed synchronous motor and a high speed synchronous motor, said low speed motor when energized from said source operating said secondary clock to correctly manifest the passing of time and said high speed motor when energized operating said secondary clock at a higher speed, two line circuits connecting said master clock and said secondary clock, contacts controlled by said master clock for energizing said circuits alternately at time intervals as measured by said master clock, means including contacts operated by said secondary clock for alternately connecting said low speed motor to one and then the other of said circuits at corresponding time intervals as measured by said secondary clock and for connecting said high speed motor to the opposite circuit during the latter part of each of said time intervals and for isolating said high speed motor from both of said circuits during the early part of at least alternate ones of said time intervals, whereby if said secondary clock is tardy it will be advanced and whereby if said secondary clock is fast it will be temporarily held stationary until correct.

4. In an alternating current clock system; the combination with an alternating current power system delivering alternating current at a frequency regulated to correctly manifest the passing of time; a master clock manifesting standard time; a secondary clock having a drive shaft, synchronous motor means for driving said shaft at a high synchronous speed or at a low synchronous speed; two circuits connecting said master clock and said secondary clock; contacts controlled by said master clock for alternately, for equal time periods as manifested by said master clock, supplying said circuits with alternating current; means including contacts controlled by said secondary clock for during a first portion of such time period as manifested by said secondary clock connecting said synchronous motor means so as to operate at a low synchronous speed and to a particular one of said circuits, for during the second portion of such time interval connecting said synchronous motor means so as to operate at a high synchronous speed and to such particular circuit and for disconnecting said synchronous motor means from such particular circuit during a third portion of such time period, whereby if said secondary clock is tardy it will be accelerated and whereby if said secondary clock is fast it will be temporarily held at rest.

5. In an electric clock system, the combination with a source of alternating current, a central location and a secondary clock location, two circuit channels connecting said central location and said secondary clock location, a master clock at said central location for alternately energizing said circuit channels from said source for equal time intervals as determined by said master clock and for energizing both of said circuit channels after each current cessation for a time period proportional to such current cessation, a secondary clock at said secondary clock location including a low speed synchronous motor and a high speed motor for driving the same, and con-

tacts controlled by said secondary clock for alternately connecting said low speed synchronous motor and said high speed motor into one and then into the other of said circuit channels for substantially equal time intervals as manifested by said secondary clock, said contacts excluding said high speed motor from one of said circuit channels for a short period of time as manifested by said secondary clock to at times stop said secondary clock, said secondary clock operating at a high speed if either said high speed motor or both said high speed and said low speed motor are energized and operating at a normal speed if only said low speed motor is energized, whereby said secondary clock is corrected after each current cessation and is additionally corrected if in error for a reason other than a current cessation.

6. A secondary clock comprising, a time shaft, a gear train, an electric motor for driving said time shaft through the medium of said gear train at a high or a low speed to cause said time shaft to correctly mainfest the passing of time when driven by said motor at a low speed and for operating said time shaft at a higher speed when driven by said motor at its high speed, two inlet terminals for said clock, means including contacts for connecting said motor to operate at a low speed alternately for equal time intervals as manifested by said secondary clock to one and then the other of said terminals and for alternately connecting said motor to operate at a high speed to the other and then to said one of said terminals.

7. A secondary clock comprising, a time shaft, a gear train, a high speed electro-responsive driving means and a low speed electro-responsive driving means for driving said time shaft through the medium of said gear train to cause said time shaft to correctly manifest the passing of time when driven by said low speed driving means and for operating said time shaft at a higher speed when driven by said high speed driving means, two inlet terminals for said clock, means including contacts for connecting said low speed driving means alternately for equal time intervals as manifested by said secondary clock to one and then the other of said terminals and for alternately connecting said high speed driving means to the other and then to said one of said terminals, said high speed driving means being at least at times as manifested by said secondary clock disconnected from both of said terminals.

8. In an electric 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 in combination a mechanical time measuring means and a synchronous motor for accurately manifesting the passing of time so long as no current cessation occurs and for substantially accurately manifesting the passing of time during a current cessation, a secondary clock including a two speed synchronous motor having a high speed and a low speed circuit portion, said low speed circuit portion when energized from said source operating said secondary clock to correctly manifest the passing of time and said high speed circuit portion when energized from said source operating said secondary clock at a faster rate, line wires connecting said master clock and said secondary clock, contacts controlled by said master clock for energizing said line wires in succession from said source, and contacts controlled by said secondary clock for connecting said high speed and said low speed circuit portions to said line wires in succession in the same order in accordance with the lapse of time as manifested by said secondary clock and in a manner so that both circuit portions are not simultaneously connected to the same line wire and so that the low speed circuit portion is connected in series with that line wire with which the high speed circuit portion was last connected, whereby if the contacts controlled by said master clock are operated to shift the source of alternating current from one line wire to another before the contacts of the secondary clock have shifted said high speed circuit portion is energized.

9. In an alternating current clock system; the combination with an alternating current power system delivering alternating current at a frequency regulated to correctly manifest the passing of time; a master clock manifesting standard time; a secondary clock having a first synchronous motor to drive said secondary clock at normal speed and a second synchronous motor for driving said secondary clock at a high speed; two line circuits connecting said master clock and said secondary clock; contacts controlled by said master clock for alternately, for equal time periods as manifested by said master clock, supplying said circuits with alternating current; means including contacts controlled by said secondary clock for during a first portion of a double time period as manifested by said secondary clock connecting said first synchronous motor to a particular one of said circuits, for during the second portion of such double time interval connecting the second synchronous motor to such particular line circuit, and for at times connecting the motor not connected to said particular line circuit to the other of said line circuits; whereby if said secondary clock is tardy it will be accelerated and whereby if said secondary clock is fast it will be temporarily held at rest.

10. In an electric clock system, the combination with a source of alternating current of regulated frequency regulated to correctly manifest the passing of time, a master clock, a secondary clock including a first synchronous motor and a second synchronous motor, said first synchronous motor when energized from said source operating said secondary clock to correctly manifest the passing of time and said second synchronous motor when energized from said source operating said secondary clock at a faster rate, line circuits connecting said master clock and said secondary clock, contacts controlled by said master clock for energizing said circuits in succession from said source, and means including contacts controlled by said secondary clock for connecting said synchronous motors to said line circuits in succession in the same order in accordance with the lapse of time as manifested by said secondary clock and in a manner so that both synchronous motors are not simultaneously connected in the same line circuit and so that the first motor is connected into that line circuit into which the second motor was last connected, whereby if the contacts controlled by said master clock are operated to shift the source of alternating current from one circuit to another before the contacts of the secondary clock have operated said second synchronous motor is energized.

11. In an electric clock system, the combination with a source of alternating current having its frequency regulated to correctly manifest the passing of time, a master clock, a secondary clock including synchronous motor means having a low speed circuit and a high speed circuit, said motor

means when energized from said source through the medium of its low speed circuit operating said secondary clock to correctly manifest the passing of time and when energized through the medium of its high speed circuit operating said secondary clock at a higher speed, two line circuits connecting said master clock and said secondary clock, contacts controlled by said master clock for energizing said line circuits alternately at time intervals as measured by said master clock, means including contacts operated by said secondary clock for alternately connecting said low speed circuit to one and then the other of said line circuits at corresponding time intervals as measured by said secondary clock and for at times connecting said high speed circuit to that line circuit to which said low speed circuit is not connected, whereby if said secondary clock is tardy it is at times operated at increased speed by said high speed motor.

12. In an electric clock system, the combination with a source of alternating current having its frequency regulated to correctly manifest the passing of time, a master clock, a secondary clock including synchronous motor means having a low speed circuit and a high speed circuit, said motor means when energized from said source through the medium of its low speed circuit operating said secondary clock to correctly manifest the passing of time and when energized through the medium of its high speed circuit operating said secondary clock at a higher speed, two line circuits connecting said master clock and said secondary clock, contacts controlled by said master clock for energizing said line circuits alternately at time intervals as measured by said master clock, means including contacts operated by said secondary clock for alternately connecting said low speed circuit to one and then the other of said line circuits at corresponding time intervals as measured by said secondary clock and for connecting said high speed circuit to the opposite circuit during the latter part of each of said time intervals and for isolating said high speed circuit from both of said circuits during the early part of at least alternate ones of said time intervals, whereby if said secondary clock is tardy it will be advanced and whereby if said secondary clock is fast it will be temporarily held at stop until correct.

13. In combination, a master time shaft, a secondary time shaft, an alternating current synchronous motor for driving said secondary time shaft, a source of alternating current, a first and a second circuit for energizing said synchronous motor to cause said synchronous motor to drive said secondary time shaft at a low and a high speed respectively, two current channels connecting said master clock and said secondary clock, commutating means controlled by said master time shaft to energize said current channels from said source alternately for substantially equal time intervals, and contacts controlled by said secondary time shaft for alternately connecting one of said current channels to said first and the other of said current channels to said second circuit and then connecting said one current channel to said second circuit and said other current channel to said first circuit, whereby said secondary time shaft will be re-synchronized with said master time shaft after each temporary current cessation.

14. In combination, a master time shaft, a secondary time shaft, an alternating current synchronous motor for driving said secondary time shaft, a source of alternating current, a first and a second circuit for energizing said synchronous motor to cause said synchronous motor to drive said secondary time shaft at a low and a high speed respectively, two current channels connecting said master clock and said secondary clock, commutating means controlled by said master time shaft to energize said current channels from said source alternately for substantially equal time intervals, and contacts controlled by said secondary time shaft for alternately connecting one of said current channels to said first and the other of said current channels to said second circuit and then connecting said one current channel to said second circuit and said other current channel to said first circuit for time periods substantially equal to said time period as measured by said secondary time shaft, whereby said secondary time shaft will be re-synchronized with said master shaft after each temporary current cessation.

15. In an electric clock system, the combination with a source of alternating current, a central location and a secondary clock location, two circuit channels connecting said central location and said secondary clock location, a master clock at said central location for alternately energizing said circuit channels from said source for equal time intervals as determined by said master clock and for energizing both of said circuit channels after each current cessation for a time period proportional to such current cessation, a secondary clock including synchronous motor means having two lead-in wires and for driving time manifesting means of said secondary clock at a normal speed or at a high speed depending upon which of the two lead-in wires are connected to an energized circuit channel, and contacts controlled by said secondary clock for alternately connecting said lead-in wires to one and then the other of said circuit channels for substantially equal time intervals as manifested by said secondary clock, said contacts excluding the lead-in wire which operates said synchronous motor means at said high speed from both of said circuit channels for a short period of time as manifested by said secondary clock to at times stop said secondary clock, whereby said secondary clock is corrected after each current cessation and is additionally corrected if in error for any reason.

16. A secondary clock comprising, a time shaft, a gear train, synchronous motor means for driving said time shaft through the medium of said gear train to cause said time shaft to correctly manifest the passing of time when an alternating current source of regulated frequency is connected to one terminal of said synchronous motor means and for operating said time shaft at a higher speed when said source is connected to the other terminal of said synchronous motor means, two inlet wires for said clock, means including contacts operated by said time shaft for connecting said one terminal alternately for equal time intervals as manifested by said secondary clock to one and then the other of said inlet wires and for alternately connecting said other terminal first to said other inlet wire and then to said one inlet wire.

17. A secondary clock comprising, a time shaft, a gear train, synchronous motor means for driving said time shaft through the medium of said gear train to cause said time shaft to correctly manifest the passing of time when an alternating current source of regulted frequency is con-

nected to one terminal of said synchronous motor means and for operating said time shaft at a higher speed when said source is connected to the other terminal of said synchronous motor means, two inlet wires for said clock, means including contacts operated by said time shaft for connecting said one terminal alternately for equal time intervals as manifested by said secondary clock to one and then the other of said inlet wires and for alternately connecting said other terminal first to said other inlet wire and then to said one inlet wire, said other terminal of said synchronous motor means being through the medium of said contacts at least at times as manifested by said secondary clock disconnected from both of said inlet wires.

18. In a synchronous motor clock system, the combination with a secondary clock including time manifesting means and a two speed synchronous motor operating at a normal speed when energized to constitute a low speed motor and operating at a high speed when energized to constitute a high speed motor even though it is energized from the same source of alternating current in both instances for driving said time manifesting means at normal speed and at high speed respectively, and means including a master clock having contacts and contacts operated by said time manifesting means for supplying alternating current to said synchronous motor so as to operate at normal speed through the greater portion of a period of time and to supply alternating current to said synchronous motor so as to operate at a high speed during a portion of such period of time in the event said secondary clock is tardy.

19. In a synchronous motor clock system, the combination with a secondary clock including time manifesting means and a two speed synchronous motor having a multiple pole and a double multiple pole stator and rotor structure and windings and for driving said time manifesting means to correctly manifest the passing of time when said windings are connected to constitute such double multiple pole motor and energized from a source of alternating current of regulated frequency and to operate said time manifesting means at a faster rate when said windings are connected to constitute such multiple pole motor when energized from said source of alternating current of regulated frequency, and means including a master clock and contacts operated thereby to at times energize the windings of said synchronous motor to constitute a double multiple pole synchronous motor to correctly manifest the passing of time and to at other times energize the windings of said synchronous motor to constitute such multiple pole motor to correct the time indication of said secondary clock.

20. In an alternating current clock system; the combination with an alternating current power system delivering alternating current at a frequency regulated to correctly manifest the passing of time; a master clock manifesting standard time; a secondary clock including a two speed synchronous motor having a normal speed circuit portion which if energized by current from said source causes said secondary clock to correctly manifest the passing of time and having a high speed circuit portion which if energized from said source causes said secondary clock to operate at excess speed; two line circuits connecting said master clock and said secondary clock; contacts controlled by said master clock for alternately, for substantially equal time periods as manifested by said master clock, supplying said circuits with alternating current from said source; means including contacts controlled by said secondary clock for during a second portion of such time period as manifested by said secondary clock connecting said normal speed circuit portion to one of said line circuits and connecting the high speed circuit portion to the other of said line circuits and for during a first portion of such time period connecting said normal speed circuit portion to said one line circuit and leaving the high speed circuit portion disconnected from both line circuits, whereby if said high speed circuit portion is connected to a live line circuit when said secondary clock reaches the end-of-time period position the secondary clock will be stopped but if said normal speed circuit portion is connected to a live line circuit when the secondary clock reaches such end-of-time period position and at a time when said master clock shifts energy from one line circuit to the other said secondary clock will continue to operate at normal speed.

21. In combination, a master time shaft, a secondary time shaft, an alternating current synchronous motor for driving said secondary time shaft, a source of alternating current, a first and a second circuit for energizing said synchronous motor to cause said synchronous motor to drive said secondary time shaft at a low and a high speed respectively, two current channels connecting said master clock and said secondary clock, commutating means controlled by said master time shaft to energize said current channels from said source alternately for substantially equal time intervals, one contact means controlled by said secondary time shaft for alternately connecting said first circuit to said current channels alternately for substantially said time intervals as determined by said secondary time shaft, and another contact means controlled by said secondary time shaft for during a first portion of such time period connecting said second circuit to the one current channel to which said first circuit is not connected and for during a second portion of such time period connecting said second circuit to the other of said current channels.

22. In combination, a master time shaft, a secondary time shaft, an alternating current synchronous motor for driving said secondary time shaft, a source of alternating current, a first and a second circuit for energizing said synchronous motor to cause said synchronous motor to drive said secondary time shaft at a low and high speed respectively, two current channels connecting said master clock and said secondary clock, contact means controlled by said master time shaft to energize said current channels alternately for substantially equal time intervals two such time intervals constituting a time period; and contacts controlled by said secondary time shaft for during a first portion of such time period as determined by said secondary time shaft leaving said second circuit disconnected from both current channels and connecting said first circuit to one of said current channels, for during a second portion of such time period connecting said second circuit to said other current channel and connecting said first circuit to said one current channel, for during a third portion of such time period connecting said second circuit to said one current channel and connecting said first circuit to said other

current channel, and for during a fourth portion of such time period connecting said second circuit to said other current channel and connecting said first circuit to said one current channel.

23. In combination, a master time shaft, a secondary time shaft, an alternating current synchronous motor for driving said secondary time shaft, a source of alternating current, a first and a second circuit for energizing said synchronous motor to cause said synchronous motor to drive said secondary time shaft at a low and a high speed respectively, two current channels connecting said master clock and said secondary clock, contact means controlled by said master time shaft to energize said current channels alternately for substantially equal time intervals two such time intervals constituting a time period; and contacts controlled by said secondary time shaft for during a first portion of such time period as determined by said secondary time shaft leaving said second circuit disconnected from both current channels and connecting said first circuit to one of said current channels for during a second portion of such time period connecting said second circuit to said other current channel and connecting said first circuit to said one current channel, and for during a third portion of such time period connecting said second circuit to said one current channel and connecting said first circuit to said other current channel.

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