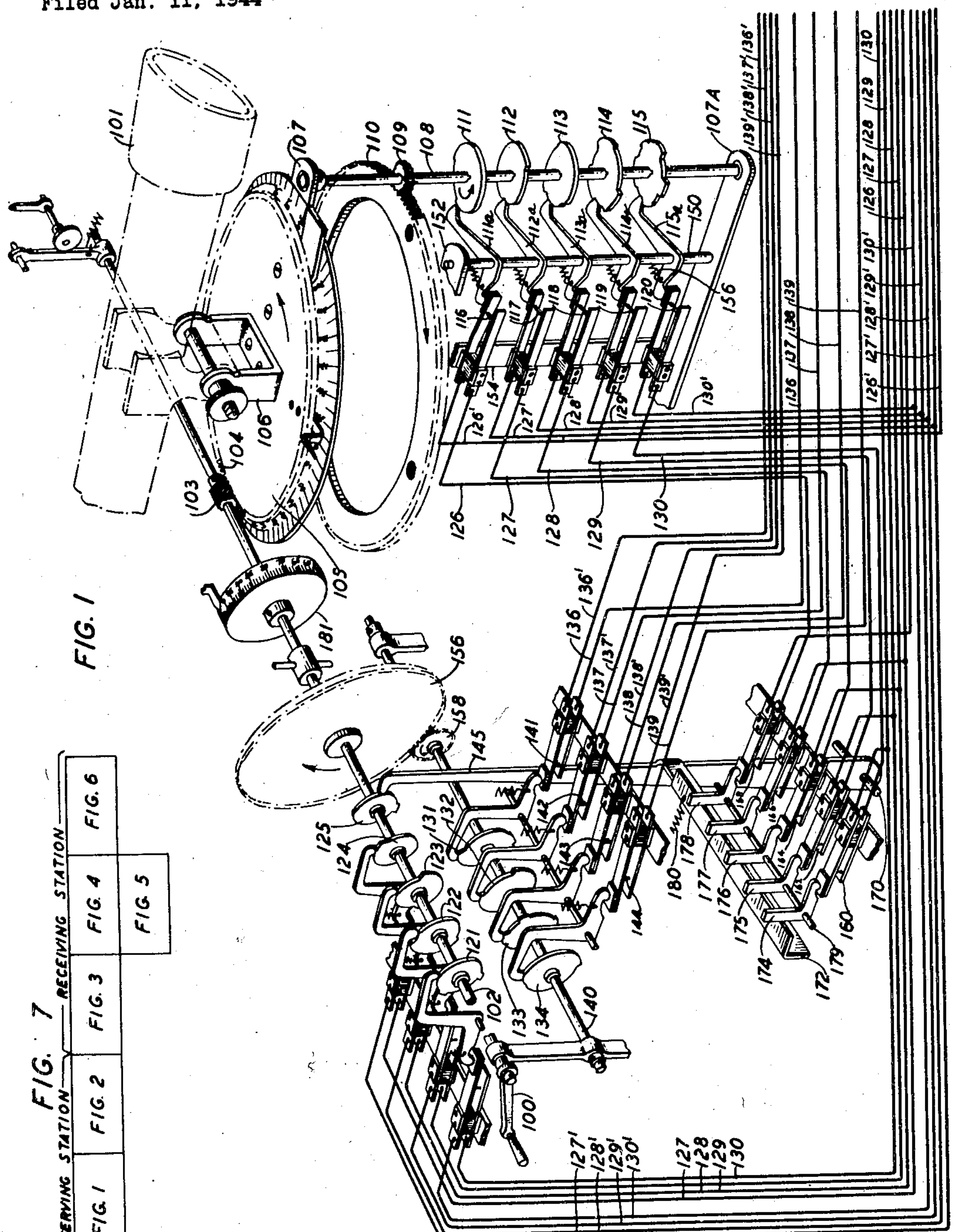
Oct. 5, 1948. F. S. KINKEAD ET AL 2,450,516

TELEMETRIC DATA TRANSMISSION SYSTEM

Filed Jan. 11, 1944 9 Sheets-Sheet 1




F. S. KINKEAD DECEASED
RITA S. KINKEAD HIS ADMINISTRATRIX
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TELEMETRIC DATA TRANSMISSION SYSTEM

Filed Jan. 11, 1944 9 Sheets-Sheet 2

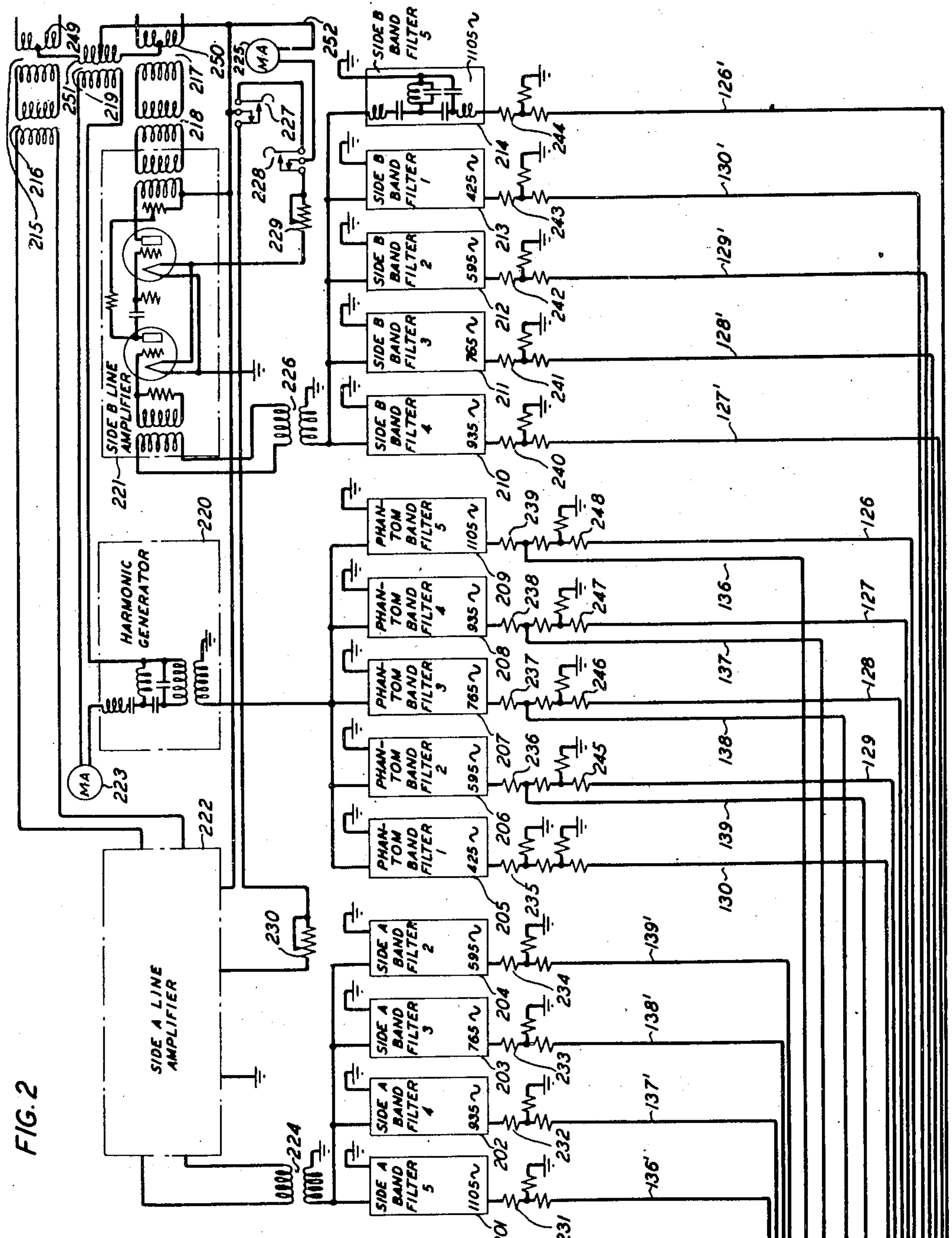


FIG. 2

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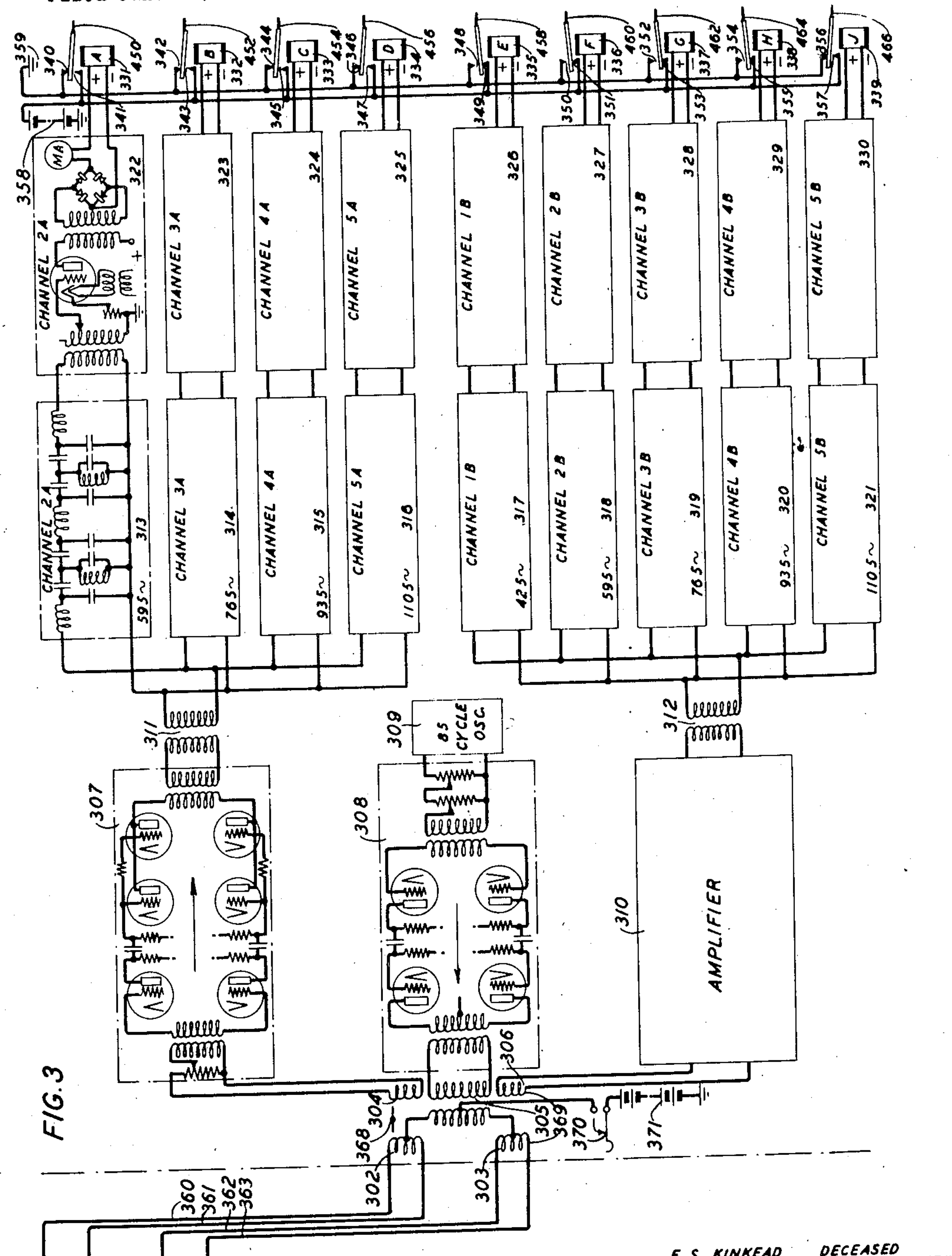


FIG. 3

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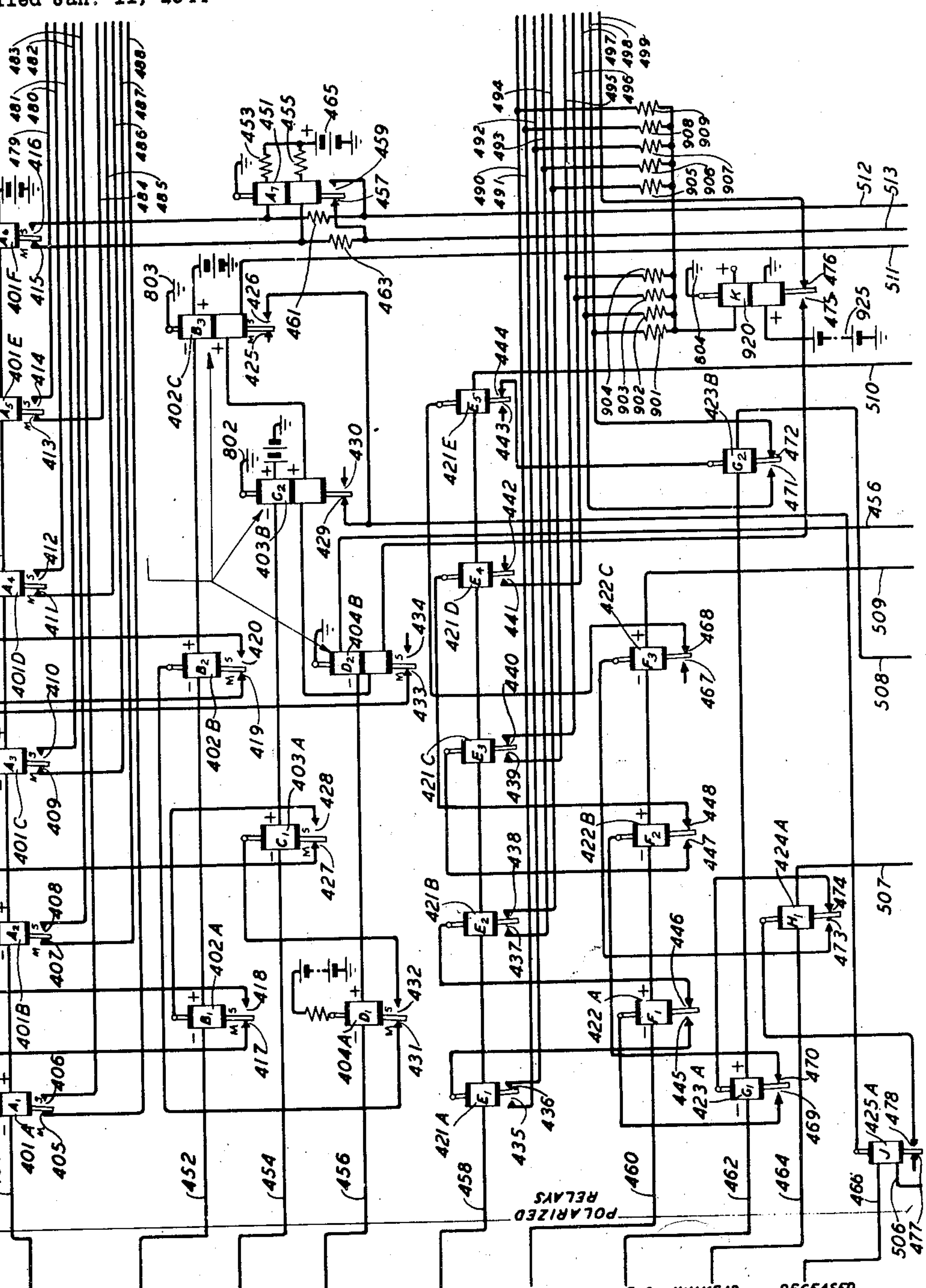

FIG. 4

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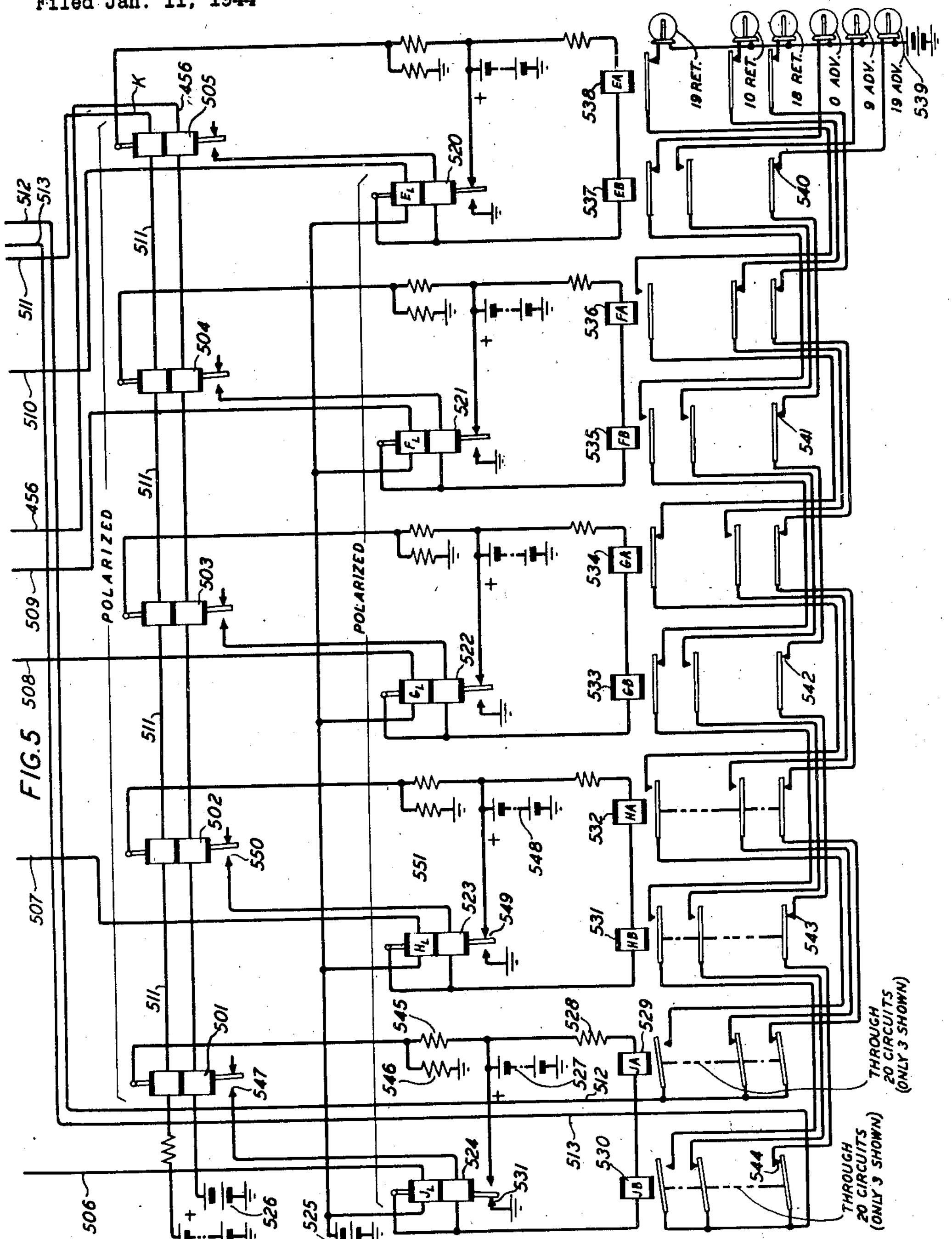
Filed Jan. 11, 1944

9 Sheets-Sheet 5

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TELEMETRIC DATA TRANSMISSION SYSTEM

Filed Jan. 11, 1944 9 Sheets-Sheet 6

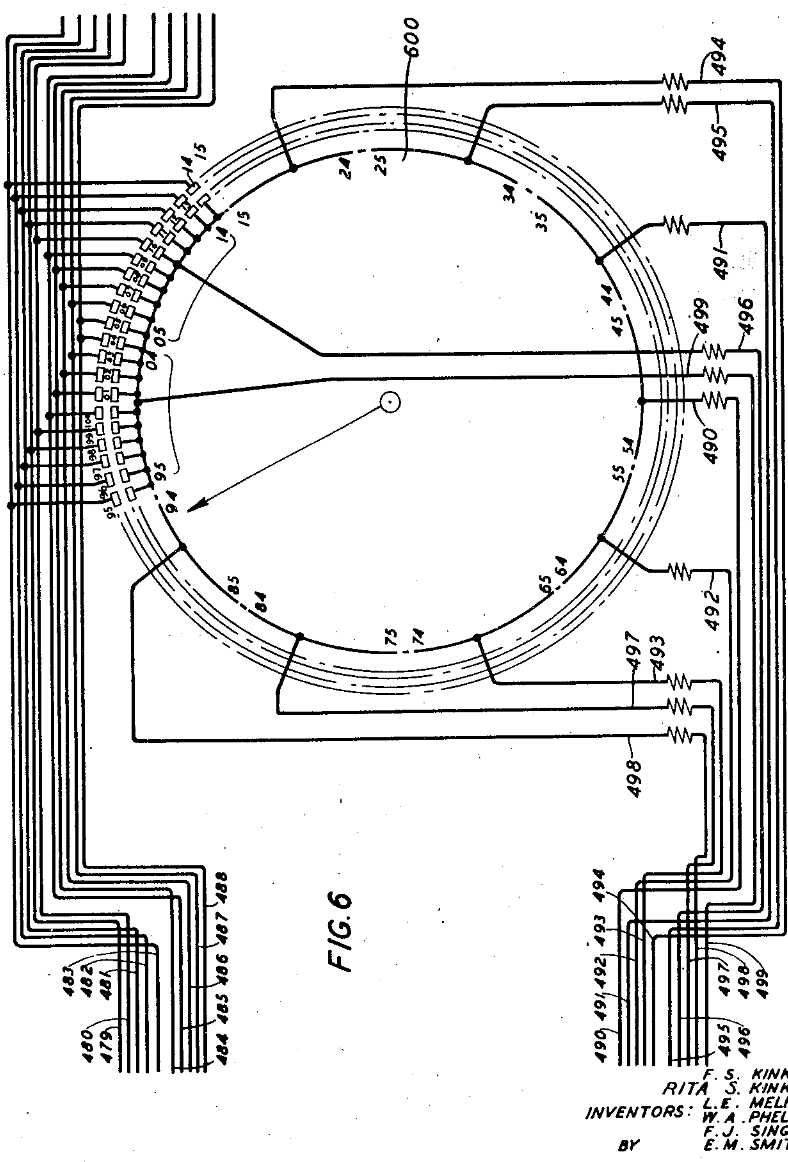


FIG. 6

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FIG. 8

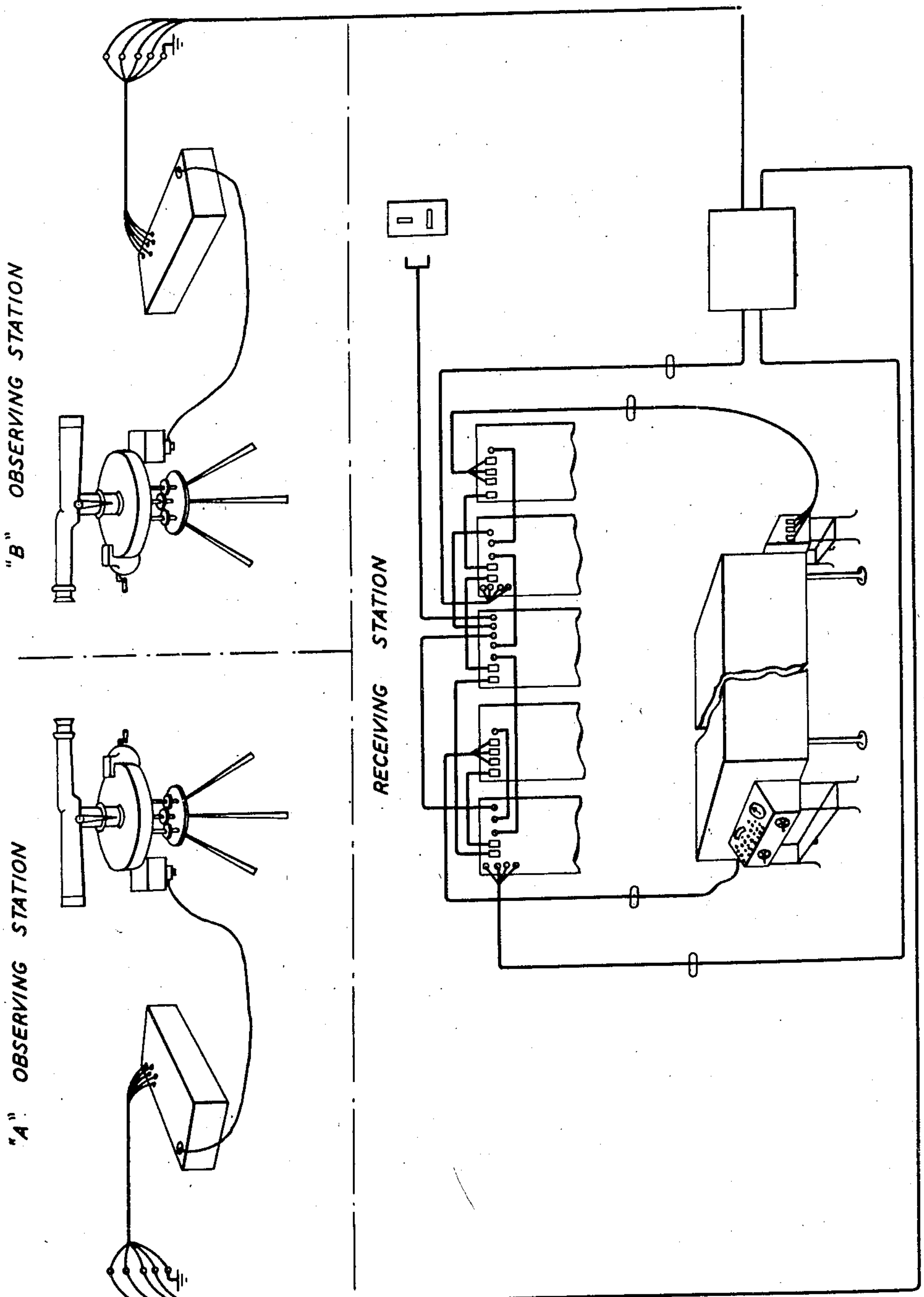


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FIG. 10

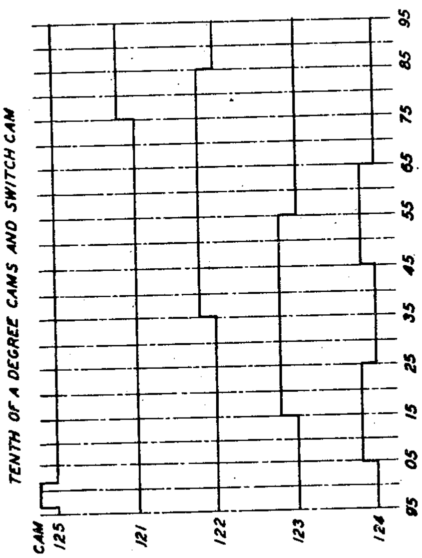


FIG. 9

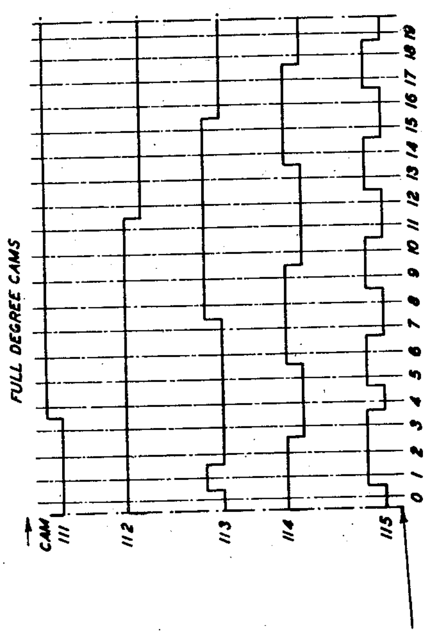


FIG. 11

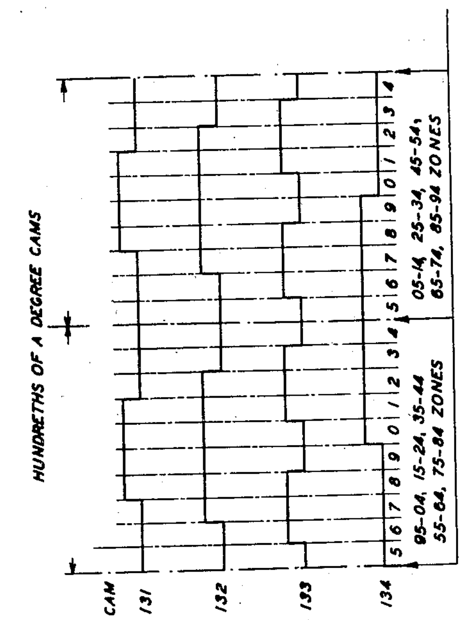


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FIG. 12

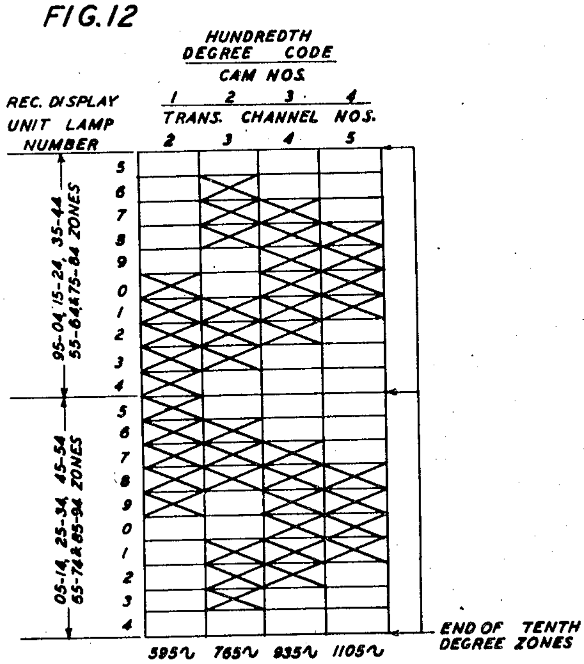



FIG. 13

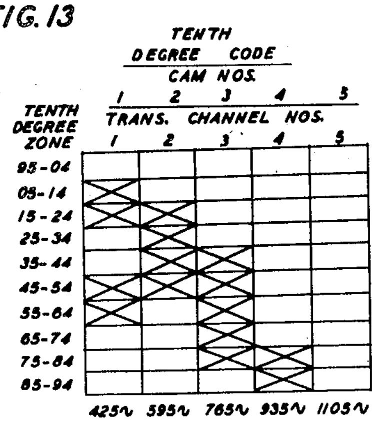
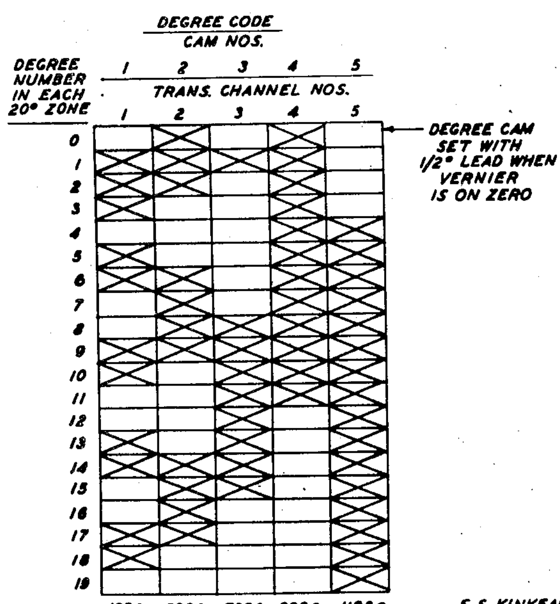



FIG. 14

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Patented Oct. 5, 1948

2,450,516

# UNITED STATES PATENT OFFICE

2,450,516

## TELEMETRIC DATA TRANSMISSION SYSTEM

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Application January 11, 1944, Serial No. 517,824

7 Claims. (Cl. 177—351)

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The invention relates to means for and methods of maintaining a receiving station continuously informed of magnitudes observed or measured at a transmitting station; more specifically it relates to improvements in systems for and methods of transmitting and in expediting the transmission of permutationally coded multifrequency alternating current electrical impulses, corresponding to multidigit numbers defining an observation or measurement, from a first station to a second station.

A system arranged for transmitting almost instantaneously permutation code direct current impulses corresponding to a multidigit number from a first station to a second station is disclosed in a patent application by Kinkead et al., Serial No. 464,564 filed November 5, 1942, and which has become Patent No. 2,406,384, Aug. 27, 1946. The exemplary system herein disclosed employs permutation codes of alternating currents of different frequencies instead of direct current in transmitting the impulses between stations and includes new transmission and selecting features.

The multidigit number which is defined by the permutation code impulses of alternating current transmitted between stations may correspond to data readings at one of the stations. The multidigit number may also designate called subscribers in a communication switching system. The multidigit number may represent gradations of shade in a picture. In fact, the multidigit number may represent a wide variety of things and conditions dependent upon the system wherein the invention herein is applied.

An object of this invention is the improvement of systems for transmitting data such as data represented by plural digit numbers from a first station to a second station.

Another object of the invention herein is the transmission of permutation codes of alternating current electrical impulses of various frequencies defining multidigit numbers which may, for instance, represent observed data from a first station to a second station almost instantaneously with the establishment of the data which define the multidigit numbers.

A feature of the invention herein is the employment of various permutation code combinations of different frequencies of alternating current to define separate portions of the same number, and transmitting the various permutation code combinations of currents of different frequencies simultaneously over a plurality of transmission channels to define an observation or measurement made at an observing station in terms of multidigit numbers to a receiving station as nearly as possible concurrently with the observations.

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A further feature of the invention comprises means and methods for generating an alternating current of a single frequency at a receiving station, transmitting said current over a transmission path extending to a second station, converting the current of a single frequency into a current of five different frequencies in a harmonic generator located at the second station, selecting various combinations of the frequencies in accordance with separate permutation codes to define separate portions of multidigit numbers corresponding to observations at the second station, retransmitting alternating currents of the various code combinations of frequencies defining the separate portions of the multidigit numbers simultaneously from the second station back to the receiving station and transmitting the currents of various code combinations of frequencies received at the receiving station through selecting devices at the receiving station to control indicating devices corresponding to the multidigit number.

A further feature of the invention is the dividing of each of the multidigit numbers representing the data to be transmitted between stations into a plurality of subgroups of digits, the number of digits in each subgroup and the number of subgroups being chosen in such manner as to minimize the number of channels required for the almost instantaneous transmission of alternating current impulses of various frequencies in accordance with a permutation code to identify the multidigit number at the receiving station.

A further feature of this invention is the separation of a multidigit number having four digits into three subgroups of digits, the assigning of two separate multielement permutation codes and two separate transmission circuits to the three subgroups, the assigning of a separate code combination to each number in each subgroup and the assigning of a number of separate alternating current channels corresponding to the number of elements in each multielement permutation code for each transmission circuit so as to permit the simultaneous transmission of code combinations of different groups of frequencies of alternating current impulses to define separate portions of the multidigit number at the receiving station at almost the same instant that an observation or measurement is made at the observing station.

Another feature of this invention is an alternating current transmission path comprising five separate channels for five different alternating current frequencies arranged for the transmission at times of permutation code signal combinations defining single digit numbers while varying the current frequency combinations impressed on only four of the five channels and for the transmission at other times of permutation code signal combinations defining two-digit numbers requiring the varying of the frequency combinations impressed on all five channels.

Another feature of this invention is the disabling of the apparatus controlled in response to the alternating current signal elements defining the single digit number when alternating current signal elements intended for the control of apparatus responsive to the two-digit number are transmitted and vice versa. These and other features of the invention will become apparent from the following description when read with reference to the associated drawings, in which Figs. 1 to 6, which show the overall circuit, should be arranged as indicated in the block diagram per Fig. 7. Figs. 1 and 2, as indicated in Fig. 7, show equipment which is located at the observing or measuring station and Figs. 3 to 6 show the circuit interconnecting the observing or measuring station and the receiving station and the apparatus at the receiving station.

Fig. 1 represents an observing instrument, in this particular embodiment a telescope, mounted on a device for measuring the angle between the line of sight through the telescope and a base line and translating the measurement into multi-element permutation code settings of the three groups of cams, shown in the figure, which define the measurement. Each group of cams controls an individual set of electrical contacts which are either opened or closed in accordance with the particular code set up on the corresponding cams to define the measurement;

Fig. 2 shows terminating equipment for two side circuits and a phantom circuit interconnecting the observing and receiving station, as well as a harmonic generator, band-pass filtering equipment, and amplifying equipment at the observing station;

Fig. 3 shows the line equipment connecting the observing station with the receiving station, as well as an oscillator, shown in the center of the figure, for generating a single frequency alternating current and shows also two amplifiers, one associated with each incoming side circuit, two sets of band-pass filters, two sets of amplifier-rectifiers connected individually to the filters and two sets of code receiving relays connected to the rectifiers;

Fig. 4 shows two selecting circuits located at the receiving station;

Fig. 5 shows a third selecting circuit located at the receiving station;

Fig. 6 shows an indicating circuit located at the receiving station;

Fig. 7 is a diagram showing the manner in which Figs. 1 to 6 should be arranged, each in relation to the other, to form an operative system;

Fig. 8 is a diagram illustrating an embodiment of the invention herein, employed when the invention is used in an artillery range finding system. In such an arrangement, one set of equipment such as Fig. 1 and Fig. 2 combined would be required at each of two observing stations and two sets of receiving equipment, such as Figs. 3 to 6 combined, would be located at each receiving station. The position of the target would be fixed by means of a base line of known length interconnecting the two measuring instruments per Fig. 1 and the magnitude of each angle between the base line and the line of sight to the target at a particular instrument. The system will provide an almost instantaneous and continuous record of the position of the target as the position of the target changes;

Figs. 9, 10 and 11 show the cam cuttings of the three sets of cams in Fig. 1; and

Figs. 12, 13 and 14 show the codes set up on each of the three sets of cams in Fig. 1 to define the different portions of the multidigit number.

*General description*

A short general description of the invention will now be given before proceeding with the detailed description thereof.

The central or receiving station and the measuring or observing station are interconnected by two pairs of conductors, Figs. 2 and 3, which pairs of conductors are also interconnected at each end by balanced transformer coils in a well-known manner to provide a third circuit known as a phantom circuit. An oscillator, shown in the middle of Fig. 3, generating a single frequency current, is connected through an amplifier to the phantom circuit at the receiving station. At the observing station the single frequency current is transmitted from the output of the phantom circuit, as shown in Fig. 2, to a harmonic generator which translates alternating current of a single frequency into alternating current of a number of frequencies of which five are employed. All five are employed as elements in one permutation code and four of the five as elements in a second permutation code.

The output of the harmonic generator is impressed on five band-pass filters connected in parallel. The outputs of the band-pass filters are connected by conductors interconnecting Fig. 2 and Fig. 1 to three different sets of cam-controlled contacts on the measuring instrument at the observing station. In the particular embodiment of the invention described herein, the measuring instrument is arranged to measure any of the angles in a 360-degree range. The full 360-degree scale is divided into eighteen 20-degree zones. In operating the system of the invention in actual practice, a well-known counting circuit is employed at the receiving station which counts and indicates at the receiving station the actual 20-degree zone in which an observation or measurement is momentarily being made. The particular 20-degree zone in which a series of measurements are started is disclosed to the attendant at the receiving station by means of some complementary communication facility such as by telephone or telegraph.

A measurement made at the observing station within any 20-degree zone may be expressed by any four-digit number in the range from 00.00 to 19.99. The number is first separated into three parts. A first code is assigned to the digits in the hundredths place. A second code is assigned to the digits in the other three places combined, namely, the tenths place, the units place and the tens place. To define any of the hundredths digits ten code combinations are required. A four-element, two-condition code is assigned for this purpose. This provides a total of $2^4$ or sixteen code combinations of which ten only are employed. To define the digits for the other three places, a total of thirty code combinations is required. Ten of these are used to define the ten digits in the tenths place and twenty are used to define the twenty full units numbers in the range from 0 to 19. A five-element, two-condition code providing $2^5$ or thirty-two code combinations is provided for this purpose, of which thirty only are employed.

Two two-wire side circuits of the phantom group are employed in transmitting the signals of the two permutation codes. One of the side circuits is used in transmitting the permutation code signals which define the digits in the hundredths of a degree position. The other of the side circuits is used in transmitting the permutation code signals which define the digits in the other three places. The circuit which is used for the code signals defining the hundredths digits consists of four channels, one for each element of the four-element permutation code. The circuit which is used for the other three digits has five channels, one for each element of the five-element permutation code.

In this invention, in order to avoid loss of time in defining measurements at the receiving station, all of the digits in the four-digit number in the range from 00.00 to 19.99, 20.00 to 39.99 . . . or 340.00 to 359.99 are defined simultaneously at the receiving station and at almost the same instant that the measurement is made at the observing station. And in order to effect economy in the number of transmission circuits employed, only two two-wire transmission circuits, one having four alternating current channels and the other having five alternating current channels are used. It would appear that the limit of such a system, unless the transmission of codes defining certain of the digits in different places in the number were effected on a time discrimination basis at a sacrifice in time, would be the simultaneous definition of a three-digit number in the range from 000 to 319. That is to say, the four-element channel could define digits in the right-hand position in the range from 0 to 9 and the five-element channel could define digits in the two left-hand positions in the number in the range from 0 to 31, if both portions of the number were to be defined simultaneously and at almost the same instant that the observation was made. The manner in which all of the digits in any number from 00.00 to 19.99 are defined at the receiving station simultaneously and at almost the same instant that the measurement is being made at the observing station, while employing only two two-wire circuits, one having four and the other having five alternating current channels involves a novel arrangement of the five channel circuit and a novel arrangement of three different selecting circuits at the receiving station.

The four-channel circuit which, as mentioned above, defines the digits in the right-hand or hundredths position, transmits the four alternating current signal elements of the four-element permutation code simultaneously to a single four-switch selecting circuit at the receiving station. As the hundredths digits change in accordance with the changing measurements, the four-channel circuit and the four-switch selector which it controls and to which it is permanently connected are available at all times to transmit code combinations and make almost instantaneous selections defining the measurement. In the case of the five-element channel and the five-element code, as mentioned above, ten of the five-element code combinations define the digits in the tenths position and twenty define the



digits in the units and tens positions. During the time while the five-element codes defining the tenths digits from 1 to 9 are being transmitted, it is of course not necessary to make a transition in the units or tens digits. It is obviously necessary to make such a transition only during a short interval comprising a portion of the time while the code for the zero tenths position in the region of zero hundredths is being registered at the receiving station. The invention herein is arranged so that a selection of a particular full units digit from 0 to 19 is effected at the receiving station during a portion of the interval while a selection of a tenths zone in the range from 95 hundredths to 04 hundredths, which will be termed the zero tenths position herein, is maintained.

In addition to the selector for the hundredths digits mentioned above, two separate multiswitch selectors, one for tenths of a unit and one for full units from 0 to 19, are employed at the receiving station. Advantage is taken of the fact that the selection to be made by the tenths selector is always the same, viz., the selection for zero tenths, when a full units selection is made. One of the five-element code combinations is a combination in which no current is transmitted for any of the five-signal elements. This code combination is assigned to zero tenths. It is not necessary to actually transmit any current impulses over the five-element circuit in order to effect the selection of the zero tenths. This selection is effected by the tenths selector in response to the transmission of no current impulses over the five-element circuit. During a portion of the interval, while the measuring instrument is in the zero tenths zone, viz., while it is also in the region of zero hundredths, the full units selector is conditioned through the cooperation of both the hundredths selector and the tenths selector to receive a code defining the full units. This will involve the transmission of five-element code signals over the five-element circuit to which both the tenths-of-a-degree selector and the full units selector are connected. This tends to affect the zero tenths selection. But while this condition prevails the tenths-of-a-unit selector is conditioned by the hundredths-of-a-unit selector so that the tenths of a unit selection of zero tenths remains unaffected.

It is thus possible by means of the invention herein to control both the tenths-of-a-degree selector and the full units selector by means of one transmission circuit so that each effects a selection simultaneously. The zero tenths selection by the tenths selector is maintained while the full units code is being received over the same circuit which serves both.

In the drawings, the output side of each of four of the five band-pass filters connected to the output of the harmonic generator in the middle of Fig. 2 is connected to a different contact controlled by each of the hundredths of a degree cams, which are the four cams secured to the lower of the two horizontal cam shafts in Fig. 1. A different code combination of the four frequencies is passed to define the position of the observing instrument **101** in each of the ten hundredths degree positions in each tenth of a degree. The selected code signal combinations are impressed on the input side of the four band-pass filters shown at the left of Fig. 2. They are impressed on the primary of the transformer connected to the output of the four band-pass filters at the left of Fig. 2 in parallel through the secondary of the transformer, and through a line amplifier, on the upper side circuit extending to the receiving station. In the receiving station they are amplified in the top amplifier shown in Fig. 3 and are impressed through the four band-pass filters connected to the output of the amplifier on individual amplifier-rectifiers to operate individual relays connected to the output of the amplifier-rectifier. The four selecting relays shown in the right upper portion of Fig. 3 control a selecting circuit shown at the top of Fig. 4, comprising four sets of relay switches, which effect a selection of a hundredths of a degree indicator in the indicator circuit of Fig. 6.

The cams for the hundredths of a degree codes are arranged so that in turning through one-half of a revolution they establish ten different codes to define ten different hundredths of a degree and in turning through the second half of a revolution they repeat the codes in reverse order to define each of the succeeding ten hundredths of a degree. This may be seen from reference to Fig. 12. Reference to Fig. 12 shows also that a change in not more than one signal element is required in transitions between code combinations. This will result in a minimum of inductive disturbance during transmission of the alternating current combinations in accordance with the codes and a minimum number of changes in the switching apparatus which is one of the important aspects of the invention herein.

Attention is particularly called to the fact that although the code combinations which define the tenths of a degree digits are five-element code combinations, the particular code combinations which are assigned for the tenths of a degree are combinations in which current is never transmitted for the fifth element so that the fifth channel remains open or non-conducting at all times while defining tenths of a degree digits. This may be seen from reference to Fig. 13. Fig. 13 shows ten code combinations of the five-element code defining tenths of a degree and Fig. 14 shows twenty code combinations of the same code used in defining the full unit degrees from 0 to 19.

The output side of each of four of the five band-pass filters connected to the output of the harmonic generator in the middle of Fig. 2 is connected to a different contact controlled by each of the four tenths of a degree cams secured to the upper horizontal cam shaft in Fig. 1. A different code combination of four of the five frequencies is passed for each of ten different cam setting combinations within each full degree zone to define each tenth of a degree. The selected code combination of frequencies is passed by four of the five band-pass filters at the right of Fig. 2 through the transformer connecting the output of the right-hand band-pass filters in parallel, through the line amplifier at the upper right of Fig. 2, through the lower of the two side circuits, to the circuit per Fig. 3 at the receiving station. They are amplified in the bottom amplifier in Fig. 3, selected by four of the five band-pass filters connected in parallel to the bottom amplifier, amplified and rectified in the corresponding amplifier-rectifiers, connected to the output of the band-pass filters and then they operate four of the five relays connected to the rectifiers in various combinations while the fifth remains unchanged in a particular position in accordance with the code. The relays in turn control the lower selecting circuit shown in Fig. 4 which selects the tenth of a degree corresponding to the particular code combination or the circular lamp band indicator per Fig. 6.



The output side of each of the five band-pass filters connected to the output of the harmonic generator in the middle of Fig. 2 is connected at intervals, when full degree code signal combinations are to be transmitted, by means of a cam-controlled switch at the left in Fig. 1 to a different contact controlled by each of the five full unit degree cams, which are the five cams secured to the vertical cam shaft in Fig. 1. A different code combination of currents of the five frequencies is passed for each of the twenty different combinations of cam settings of the full units cams. Currents of frequencies in accordance with the particular code combinations are transmitted over the same circuit heretofore described, except that conditions on all five channels are varied in defining the full degrees. The five relays at the bottom right of Fig. 3 are operated in accordance with the code. The settings of these relays in turn control the selecting circuit in Fig. 5 to indicate the corresponding full degree position.

The selecting mechanism per Fig. 5 for the full units selection is locked at all times except during a short interval while the measuring instrument is in the region of zero tenths of a degree and zero hundredths of a degree. This interval is determined by the cooperation of the tenths selector and the hundredths selector.

In the case of the five-element channel, ordinarily the tenths of a degree cam contacts in Fig. 1 are connected to its transmitting circuit and the full degree contacts are disconnected except for the short interval while full degree code signal combinations are to be transmitted. This is accomplished by means of switch **145** in Fig. 1 which is controlled by cam **125**. The zero tenths of a degree zone extends from 95 hundredths to 04 hundredths. As shown in the top line of Fig. 13 no current is transmitted for any element of this code combination. Cam **125** operates switch lever **145** to close contacts **160** to **168** to connect the five channels to the full degree cams **111** to **115** during a portion of the interval while the tenths of a degree cams are in the zero tenth zone. At all other times the full unit degree cams are disconnected from the channel.

The cooperation of the hundredths of a degree selecting circuit at the top of Fig. 4 and the tenths of a degree selecting circuit at the bottom of Fig. 4 controls the indicator circuit in Fig. 6 so as to light a particular one of the hundred lamps in the lamp bank **600** to identify the particular hundredth of a degree position corresponding to the line of sight through the telescope. The selecting circuit per Fig. 5 alone selects an indicator to designate the corresponding full degree position.

The mechanism is arranged to provide a proper indication whether the movement of the target and the measuring instrument is such that the measured angle is increasing or decreasing.

*Detailed description*

Refer now to Figs. 1, 2 and 3. A telescope **101** is directed at the target. The particular twenty-degree zone within which the line of sight to the target is located is made known to the attendant at the central station by means of a separate telephone or telegraph circuit (not shown). Once the target is sighted, the telescope **101** is continuously directed at the target by the observer who will turn the vernier crank **100** to rotate shaft 102 in such manner as to maintain the line of sight through the telescope on the target. As the vernier crank is turned, the telescope is rotated by means of worm 103 which is rigidly secured to the vernier shaft. Worm 103 engages with a circular rack gear 104 on the outer surface of a disc 105 to the center of which the telescope 101 is rigidly secured by means of the U-shaped leveling and clamping device 106. One complete rotation of the vernier shaft 100 rotates telescope 101 through one degree through the cooperation of worm gear 103 and rack gear 104, which have a ratio of 360 to 1. As telescope 101 is rotated, the radial horizontal arm 107 rigidly secured to disc 105 is rotated with it. The outer end of radial arm 107 forms a bearing for the upper end of vertical cam shaft 108 the lower end of which is supported and secured in a bearing in the right-hand end of rotatable radial arm 107A. The left-hand end of the lower radial arm 107A is secured in a bearing, not shown, in vertical alignment with the vertical axis of the disc 105 about which radial arm 107A rotates as a center. A pinion 109 is secured to shaft 108 in position intermediate the ends of the shaft 108 to engage ring gear 110 which is concentric with disc 105 and rigidly secured to a tripod, not shown, used to support the observing instrument and its associated mechanism.

As the vernier crank is turned the disc or platform 105 supporting the telescope 101 is rotated. Radial arms 107 and 107A move in unison with the disc 105 revolving with them cam shaft 108.

A rotatable radial arm 152 which is shorter than and arranged in vertical alignment with arms 107 and 107A has its left-hand end, not shown, fixed in a bearing in alignment with the vertical axis of disc 105. Vertical bell crank cam follower shaft 150 is secured in an upper bearing at the right-hand end of rotatable radial arm 152 and in a lower bearing and support intermediate the ends of arm 107A. Vertical contact support plate 154 is welded at its lower end to arm 107A and at its upper end to arm 152. Cams 111 to 115 are spaced vertically along cam shaft 108, and rigidly secured to the shaft. Bell crank cam followers 111A to 115A are spaced vertically along follower shaft 150 in positions corresponding to the cam positions. Pairs of cooperating contacts 116 to 120 are spaced vertically along plate 154. The right-hand end of each of the bell crank followers is maintained in engagement with its respective cam by a tensioned spring such as 156, the left-hand end of which is secured to the left-hand end of the follower and the right-hand end of which is secured to fixed follower shaft 150. Where the periphery of any of cams 111 to 115 is depressed the corresponding follower is rotated clockwise to disengage from its corresponding contact and the contact is open. When the periphery is raised the corresponding follower is rotated in a counter-clockwise direction to engage the contact and the contact is closed. The entire assembly comprising radial arms 107, 107A and 152, vertical shafts 108 and 150, vertical bar 154, pinion 109, cams 111 to 115, followers 111A to 115A with their associated springs and contacts 116 to 120 revolve as a unit about the vertical axis of disc 105 as the telescope 101 is rotated while maintaining a fixed relationship between the units of the revolving assembly.

As the shaft 108 revolves, pinion 109 engages ring gear 110. Thus shaft 108 while revolving about the vertical axis of disc 105 and telescope 101 as a center, rotates also about its own center. The ratio of the gear 110 to gear 109 is such that shaft 108 rotates about its own axis once while revolving through twenty degrees about the vertical axis of disc 105. The five full degree cams 111 to 115 are arranged to control their corresponding contacts through their associated bell crank followers 111A to 115A in accordance with the permutation code shown in Fig. 14 so as to transmit twenty different combinations of a group of five alternating current frequencies for each rotation of shaft 108 to identify each of the twenty different full degree divisions within each of the eighteen sectors into which the observing circle is assumed to be divided. Each of cams 111 to 115 therefore is divided into twenty equal segments, each arranged to either open or close its respective contact to provide twenty code combinations for each revolution of shaft 108 to define each of the twenty degrees as indicated in Fig. 14.

Mounted on the horizontal vernier crank shaft 102 are five cams 121 to 125. Shaft 102 and each of cams 121 to 125 rotate once for each one-degree change in position of telescope 101. Four of these cams, 121 to 124, are used to control the transmission of combinations of alternating current of various frequencies in accordance with a permutation code, shown in Fig. 13, to define each of the ten tenths of a degree within each degree. Each cam controls a bell crank follower which opens and closes a corresponding contact. The four cams 121 to 124 in rotating once set up ten different permutation code combinations of settings of their bell crank followers and the contacts controlled by their followers. The fifth cam, cam 125, is used in controlling a switch 145 the function of which is to control the times of transmission of the full degree code combinations. It will be explained below. Cam shaft 140 is coupled to cam shaft 102 through spur gears 156 and 158 which have a ratio of one to five. Mounted on shaft 140 are the four hundredth of a degree cams 131 to 134 which control their respective contacts 141 to 144 through four bell crank levers. In turning through one-half of a rotation cams 131 to 134 set up ten different code combinations of contacts 141 to 144 to define each of the ten hundredths of a degree divisions in each tenth of a degree. In turning through the second half of a revolution the code combinations are repeated in reverse order. The code is shown in Fig. 12. Reference to this figure shows that there are only ten distinctive codes. These are shown in the top ten horizontal lines of Fig. 12. The codes are repeated in reverse order. The code shown in the eleventh line from the top is the same as the code in the tenth line from the top. The code shown in the first horizontal line is not repeated until it appears in the twentieth line. Reference to succeeding codes shows that not more than a single element changes condition at any time.

*Transmission of hundredths of a degree information*

The manner in which the hundredths of a degree information is transmitted from the observing station to the central station will first be described.

Key 370, Fig. 3, is closed which establishes a circuit from grounded battery 371 through key 370, over the four conductors 360, 361, 362 and 363 in parallel, through conductor 252 in Fig. 2 to parallel branches. One branch extends through ammeter 225, key 228 and variable resistance 229 to the filaments of tubes in amplifier 221. The second branch supplies plate current to the tubes. Each branch is multiplied to a corresponding circuit in amplifier 222.

A single frequency alternating current, preferably eighty-five cycles, is developed in the oscillator indicated by rectangle 309 in Fig. 3. It is amplified in amplifier 308 and transmitted through transformer 305, the secondary of which is connected to the mid-point of the secondaries 302 and 303 of transformers 368 and 369 respectively. Conductors 360 to 363 which connect the secondaries of transformers 302 and 303 to the observing station form a phantom group comprising two side circuits. Conductors 360 and 361 form one side circuit. Conductors 362 and 363 form the second side circuit. The first side circuit is terminated in winding 249 of transformer 215; the second side circuit is terminated in winding 250 of transformer 217. The mid-points of coils 249 and 250 are interconnected through coil 251 of transformer 219. The single frequency voltage provided by oscillator 309 is impressed through the secondary of transformer 219 on the input of harmonic generator 220. Milliammeter 223 in the circuit interconnecting the secondary of transformer 219 and the input of harmonic generator 220 provides an indication of the amount of current flowing in the input circuit of the harmonic generator. In response to the alternating voltage of eighty-five cycles impressed on the input of the harmonic generator 220, alternating voltages of the odd harmonics of eighty-five cycles are impressed on the input of band-pass filters 205 to 209. Band-pass filters 205 to 209 are arranged to pass current of 425, 595, 765, 935 and 1105 cycles or the fifth to thirteenth odd harmonics respectively.

When the cams 131 to 134 raise their respective followers in accordance with the various permutation code combinations, contacts 141 to 144 respectively, are closed. When contact 141 is closed, a circuit is established which interconnects the output of band-pass filter 209 which passes current of 1105 cycles through resistance 239, conductor 136, contact 141, conductor 136′, resistance 231, and filter 201, which also passes current of 1105 cycles to the primary winding of transformer 224. When cam 132 raises its follower contact 142 is closed. The output of band-pass filter 208, 935 cycles, is connected through resistance 238, conductor 137, contact 142, conductor 137′ and band-pass filter 202, 935 cycles, to the primary of transformer 224. When cam 133 raises its follower contact 143 is closed. This establishes a circuit connecting the output of filter 207, 765 cycles, through resistance 237, conductor 138, contact 143, conductor 138′, resistance 233 and filter 203, 765 cycles, through the primary of transformer 224. When cam 134 raises its follower, contact 144 is closed. This establishes a circuit connecting the output of filter 206, 595 cycles, through resistance 236, conductor 139, contact 144, conductor 139′, resistance 234, and band-pass filter 204, 595 cycles, through the primary of transformer 224.

The code combinations established by cams 131 to 134 and contacts 141 to 144 to define the hundredths-degree settings of telescope 101 are shown in Fig. 12. Combinations of alternating voltages of frequencies in accordance with the code shown in Fig. 12 are impressed through the secondary of transformer 224. They are amplified in amplifier 222 and impressed through transformers 216



and 215 on the side circuit comprising conductors 360 and 361. They are impressed through windings 302 and 304 of transformer 368 on amplifier 307. From the output of amplifier 307 they are impressed through transformer 311 on the inputs of band-pass filters 313 to 316 inclusive, each one of which is arranged to pass a different one of the four frequencies.

Current of 595 cycles will be transmitted through band-pass filter 313. It will be amplified and rectified in amplifier-rectifier 322 and energize relay 331. Currents of 765, 935 and 1105 cycles will pass through band-pass filters 314, 315 and 316 respectively. They will be amplified and rectified in amplifier-rectifiers 323, 324 and 325 respectively, and will energize relays 332, 333 and 334 respectively. When contacts 141 to 144 in Fig. 1 are closed, relays 331 to 334 respectively will be conditioned so that their respective armatures will be in engagement with contacts 340, 342, 344 and 346. Under this condition ground 359 will be connected to the armatures of these relays. When contacts 141 to 144 are open relays 331 to 334 will be conditioned so that their respective armatures will be in engagement with contacts 341, 343, 345 and 347 respectively. Under this condition battery 358 will be connected to the armatures of the relays. Relays 331 to 334 will be conditioned in accordance with the code combinations shown in Fig. 12 when the line of sight through telescope 101 is in the hundredths position indicated in Fig. 12.

When the armature of relay 331 is operated to close contact 340, a circuit is established from ground through contact 340, conductor 450, and the windings of relays 401A, 401B, 401C, 401D, 401E and 401F to battery actuating the armatures of these relays toward the left. When the armature of relay 332 is operated to engage contact 342, a circuit is established from ground 359 through contact 342, conductor 452, windings of relays 402A, 402B and the top windings of relay 402C to battery, actuating the armatures of relays 402A and 402B to the left. When the armature of relay 333 is actuated to close contact 344, a circuit is established from ground 359 through contact 344, conductor 454, winding of relay 403A and the top winding of relay 403B to battery actuating the armature of relay 403A to the left. When the armature of relay 334 is actuated to close contact 346, a circuit is established from ground through contact 346, conductor 456, winding of relay 404A, top winding of relay 404B and the bottom windings of relays 505, 504, 503, 502 and 501 to 65-volt battery 526. The armature of relays 404A will be actuated to the left. The manner in which relays 402C, 403B, 404B and 501 to 505, all of which have more than one winding, are affected by the operation of relays 331 to 334 will be described hereinafter.

When the armatures of relays 331 to 334 are actuated so as to close their respective contacts 341, 343, 345 and 347, 130-volt battery 358 will be connected to the left-hand terminals of each of the relays in the paths traced above the armatures of relays 401A to 401F, 402A, 402B, 403A and 404A in Fig. 4 will be actuated to the right. It is pointed out that the magnitude of battery 358 which is of the same polarity as the battery connected to the opposite ends of these paths is of 130-volt magnitude and that the battery connected to the opposite terminals is of 65-volt magnitude.

In Fig. 12 the left-hand vertical column, under the heading "Receiving display unit lamp number," indicates one hundred numbers in the range from 0 to 99 arranged in ten groups of ten consecutive numbers each. The consecutive numbers in each group of ten start at the digit corresponding to 5. The hundred numbers are divided into two groups of fifty. Each of the two groups comprises five groups of ten. One group of fifty includes all groups of ten the first digit of the first number of which is odd. The other includes all groups of ten the first digit of the first number of which is even so that consecutive tens in each group of twenty are in different groups of fifty. The five tens in the left-hand vertical column beginning with an odd digit appear opposite the ten upper code combinations of the twenty in Fig. 12. The five tens in the left-hand vertical column beginning with an even digit appear opposite the ten lower code combinations. Attention has heretofore been called to the fact that the code combinations for the first ten consecutive numbers in a group of twenty are repeated in reverse order for the second ten consecutive numbers in a group of twenty. This is apparent from a comparison of the ten top and ten bottom horizontal divisions of Fig. 12. The code combination for 5 for instance in the upper group which corresponds to 95, 15, 35, 55 and 75 is the same as the code combination for 4 in the lower group which corresponds to 14, 34, 54 and 74. The code combination for 6 in the upper group is the same as that for 3 in the lower group, etc.

There are ten distinctive codes shown in the table per Fig. 12. There are ten corresponding distinctive selecting paths through the hundredths selecting circuit which, as has been mentioned, is the upper selecting circuit in Fig. 4. Since each code combination corresponds to one particular number in each of five groups of ten consecutive numbers and to another particular number in each of five other groups of ten consecutive numbers, each of the corresponding ten selecting paths will effect ten parallel selections consisting of two lamps in each of five groups of twenty, each of which 2 is in a different group of ten in the hundredths lamp bank 600 in Fig. 6. The selection of the particular lamp corresponding to the hundredth of a degree setting of the measuring instrument will be completed by the cooperation of the tenths selecting circuit which will simultaneously select a particular one of ten groups of ten consecutive lamps in the bank.

The various selecting paths through the selecting circuit per Fig. 4 for the hundredths of a degree will now be traced. Since the selecting paths do not extend through the armatures of relays 402C, 403B and 404B the description of the effect of the operation of these relays in response to the code signals will be deferred.

Refer to the top horizontal division of Fig. 12. This shows the code combination for the hundredth degree ending in the digit 5 in each of five of the ten one-tenth degree zones in each degree. The corresponding tenths zones are indicated in the upper half of the vertical column at the left of Fig. 12. The same code combination is shown in the bottom horizontal division of Fig. 12 which is the code for the digit 4 in each of five other of the ten one-tenth degree zones in each degree. The corresponding tenths zones are indicated in the lower half of the vertical column at the left of Fig. 12. Since none of the rectangles in the top horizontal line of Fig. 12 is cross-hatched, the armature of each of the relays in the hundredths selecting circuit is actuated to close its right-hand contact. Under this condition a circuit may be traced from battery 800 through resistance 801, contact 432, contact 428, contact 418, contact 406 and conductor 483 which connects to the top terminal of lamp 95 and lamp 14 in the first group of twenty lamps in lamp bank 600 and which is multiplied to two lamps in corresponding positions in each of four other groups of twenty lamps, not shown in detail in lamp bank 600, but the numbers of which are indicated in the left-hand vertical column of the code diagram per Fig. 12.

The second horizontal division from the top in Fig. 12 shows the code combination for the digit 6 in five of the ten groups of ten, which code combination appears also in the second division from the bottom where it identifies the digit 3 in five other groups of ten. According to the code, the armatures of relays 402A and 402B in the hundredths selecting circuit will be actuated to the left. The armatures of the other relays in the hundredths selecting paths will be actuated to the right. Under this condition a circuit may be traced from battery 800 through resistance 801, contact 432, contact 428, contact 417, contact 408 and conductor 482 to the top terminal of lamp 96 and lamp 13 in the first group of twenty lamps in the lamp bank 600. Conductor 482 is multiplied also to the top terminals of each of two lamps in positions corresponding to the positions of lamps 96 and 13 in each of four other groups of twenty lamps as indicated in the code diagram per Fig. 12.

Reference to the third horizontal division from the top in Fig. 12 shows the code combination for 7 in five groups of ten and reference to the third division from the bottom shows the same code combination for 2 in five other groups of ten. Under this condition the armatures of relays 402A, 402B and 403A in the hundredths selecting circuit per Fig. 4 will be actuated to the left. The armatures of other relays in the selecting paths for the hundredths lamps will be actuated to the right. A circuit may therefore be traced from battery 800 through resistance 801, contact 432, contact 427, contact 410 and conductor 481 which connects to the top terminals of lamps 97 and 12 in lamp group 95 to 14. Conductor 481 will connect to the top teminals of two lamps in positions corresponding to the positions of lamps 97 and 12 in lamp group 95 to 14 in each of the other four lamp groups in lamp bank 600 as indicated in the left-hand vertical column of Fig. 12.

The code combination for the digit 8 in five groups of ten is shown in the fourth division from the top in Fig. 12. The same code combination identifies the digit 1 in five other groups of ten. For this combination the armatures of relays 402A, 402B, 403A and 404A will be actuated to the left. The armatures of the other relays in the selecting paths for the hundredths lamps will be actuated to the right. Under this condition, a circuit may be traced from battery 800 through resistance 801, contact 431, contact 419, contact 414 and conductor 479 which connects to the top terminal of lamp 98 as well as to the top terminal of lamp 11 in lamp group 95 to 14. Conductor 479 will be connected also to the top terminals of two lamps in corresponding positions in each of the other lamp groups as indicated in the left-hand vertical column of Fig. 12.

Reference to the fifth horizontal division from the top in Fig. 12 shows the code for the digit 9 in five groups of ten. Reference to the fifth horizontal division from the bottom of Fig. 12 indicates that the same code identifies 0 in five other groups of ten. For this code combination, the armatures of relays 403A, 403B, 404A and 404B will be actuated to the left. The armatures of other relays in the selecting paths for the hundredths lamps will be actuated to the right. Under this condition a circuit may be traced from battery 800 through resistance 801, contact 431, contact 420, contact 412 and conductor 480 which connects to the top terminal of lamps 99 and 10 in lamp group 95 to 14 and is multiplied to the top terminals of two lamps in corresponding positions in each of the other four lamp groups.

Reference to the sixth horizontal division from the top in Fig. 12 shows the code for the 0 digit in five groups of ten. Reference to the sixth horizontal division from the bottom in Fig. 12 indicates that the same code identifies digit 9 in five other groups of ten. For this combination the armatures of relays 401A to 401F, 402A and 404A will be actuated to the left. The armatures of the other relays in the selecting paths for the hundredths lamps will be actuated to the right. For this code combination a circuit may be traced from battery 800 through resistance 801, contact 431, contact 420, contact 411 and conductor 485 which connects to the top terminal of lamp 100 and of lamp 09 in lamp group 95 to 14. Conductor 485 is multiplied to the top terminals of two lamps in positions corresponding to the positions of lamps 100 and 09 in each of the other four lamp groups as indicated in the left-hand vertical column of Fig. 12.

Reference to the seventh horizontal division from the top in Fig. 12 shows the code combination for digit 1 in five groups of ten and reference to the seventh horizontal division from the bottom indicates that the same code combination identifies digit 8 in five other groups of ten. For this code combination, the armatures of all of the relays in the hundredths selecting circuit will be actuated to the left. A circuit may therefore be traced from battery 800 through resistance 801, contact 431, contact 419, contact 413 and conductor 484 which connects to the top terminals of lamps 01 and 08 in lamp group 95 to 14 and to corresponding terminals in each of the other four lamp groups as indicated in the left-hand vertical column of Fig. 12.

Reference to the eighth horizontal division from the top in Fig. 12 shows the code combination for digit 2 in five groups of ten and reference to the eighth horizontal division from the bottom indicates that the same code combination defines digit 7 in five other groups of ten. For this combination the armatures of relays 401A to 401F, 402A, 402B and 403A will be actuated to the left and the armatures of other relays in the selecting paths for the hundredths lamp will be actuated to the right. Under this condition, a circuit may be traced from battery 800 through resistance 801, contact 432, contact 427 and contact 409 to conductor 486 which connects to the top terminal of lamps 02 and 07 in lamp group 95 to 14 and to two lamps in corresponding positions in each of the other four lamp groups.

The ninth horizontal division from the top in Fig. 12 shows the code combination for digit 3 in five groups of ten and the ninth division from the bottom shows that the same combination identifies digit 6 in five other groups of ten. For this combination the armatures of relays 401A to 401F and 402A to 402C will be actuated to the left. The armatures of other relays in the selecting paths for the hundredths lamps will be actuated to the right. Under this condition, a circuit may be traced from battery 800 through resistance 801, contact 432, contact 428, contact 417 and contact 407 to conductor 487 which connects to the top terminal of lamps 03 and 06 in lamp group 95 to 14 and to the top terminals of two lamps in corresponding positions in each of the other four lamp groups as indicated in the left-hand vertical column of Fig. 12.

Reference to the tenth division from the top shows the code for digit 4 in five groups of ten and reference to the tenth division from the bottom shows that the same combination identifies digit 5 in five other groups of ten. For this combination the armatures of relays 401A to 401F will be actuated to the left. The armatures of other relays will be actuated to the right. A circuit may then be traced from battery 800, through resistance 801, contact 432, contact 428, contact 418, contact 405 and conductor 488 which connects to the top terminals of lamps 4 and 5 in lamp group 95 to 14 and to the top terminals of two lamps in corresponding positions in each of the other four lamp groups. Reference to the left-hand vertical column of Fig. 12 indicates the numbers of the lamps in the various groups.

It has been shown that the top terminal of each of ten lamps is selected by each selecting path in the hundredths selecting circuit. One lamp is in each group of ten consecutive lamps. In order to complete the selection of any particular lamp it is necessary to select the particular group of ten corresponding to the measurement. This is the function of the tenths selecting circuit shown at the bottom of Fig. 4 which will now be explained.

*Transmission of five element code signals*

Alternating currents of the five frequencies passed by filters 205 to 209 in Fig. 2 are employed in one five-element permutation code, shown in Figs. 13 and 14 combined, to define both tenths of a degree and degrees.

The output sides of filters 205 to 209 at the observing station are connected by conductors 130, 129, 128, 127 and 126 to the observing instrument in Fig. 1. Four of these conductors 130, 129, 128 and 127, those from the outputs of filters 205 to 208, are connected at all times to the contacts controlled by the tenths of a degree cams 121 to 124. The fifth conductor 126 which connects to the output of filter 209 is not connected to the tenths of a degree cams. Reference to Fig. 13 which shows the ten five-element code combinations employed to define the ten tenths of a degree shows, in the right-hand vertical column, that the ten code combinations chosen for the ten tenths of a degree all use a no-current condition as the fifth element of the code. The reason for this will become apparent below. As the azimuth instrument changes through each degree, each of the ten code combinations shown in Fig. 13 will be established in sequence as shown in the figure. The four cams 121 to 124 will control their respective contacts in accordance with the four left-hand vertical columns in Fig. 13. The output from filter 209 which supplies current having a frequency of 1105 cycles will remain disconnected from the lower side circuit so that the fifth element of the five-element code will remain a no-current element for all ten of the tenth of a degree combinations.

Currents having various combinations of frequencies in accordance with the tenth of a degree codes, but never including frequency of 1105 cycles, will be impressed through filters 210 to 213, transformer 226, lower side-band amplifier 221, transformers 218 and 217, conductors 362 and 363, windings 303 and 306 of transformer 369, amplifier 310, transformer 312, band-pass filters 317 to 320 and amplifier rectifiers 326 to 329 to control the armatures of relays 335 to 338. Since current of 1105 cycles is never transmitted to define tenths of a degree, relay 339 will remain deenergized whenever tenths of a degree code combinations are being transmitted.

Before proceeding with the tracing of selecting paths for the tenths of a degree selections the manner in which the five-element code combinations which define the twenty full degrees are transmitted will be described.

All five of the conductors 126 to 130 which connect to the outputs of filters 205 to 209 instead of being connected directly to the five full degree cam contacts 116 to 120 are connected to contacts 168, 166, 164, 162 and 160 of a multiple switch. The contacts are normally open. They are closed to connect the output of filters 205 to 209 to the full degree contacts only through a range of six hundredths of a degree, when the observing instrument is in the position from 97 hundredths to 02 hundredths of a degree. Shortly before the observing instrument moves into the hundredths zone from 97 to 02 in any degree, both on increasing and decreasing measurements, cam 125 will move switch arm 145 clockwise about fixed pin 170. Switch bar 172 will rotate angle levers 174 to 178 clockwise about rod 179 against the influence of individual springs such as 180 to close contacts 160, 162, 164, 166 and 168 during this interval. At such times the various five-element current and no-current code combinations which have been set up in advance on contacts 116 to 120 by cams 111 to 115 to define the particular one of the twenty full degree settings of the azimuth instrument in each of the eighteen different 20-degree zones will be transmitted over the path traced for the lower side circuit. Since the various code combinations employed to define the full degrees includes signal elements in which the fifth element is a current condition which is evident from the right-hand column of Fig. 14, current of 1105 cycles will be included in various combinations. It will be passed through side-band filters 214 in Fig. 2 and 321 in Fig. 3, amplified and rectified in amplifier-rectifier 330 to energize relay 339.

A current condition, indicated by a cross-hatched rectangle in Fig. 13, for an element in a code combination for the tenths of a degree, or in Fig. 14 for a full degree code combination, will energize the corresponding relay of the group 335 to 339 and will operate the corresponding armature to engage its upper contact. For a no-current condition indicated by a blank rectangle in Figs. 13 or 14 the corresponding armature will be operated to engage its lower contact.

At this point attention is called to the fact that relays 335 to 339 receive the code combinations for both tenths of a degree and full degrees. The relays impress the code combinations on paths which extend through the windings of selecting relays in the tenths of a degree selecting circuit in the lower portion of Fig. 4 and in series through the windings of selecting relays in the full degree selecting circuit in Fig. 5. The full degree selecting circuit is ordinarily locked so that it cannot respond to the tenth degree combinations. The tenth of a degree selector per Fig. 4 is disabled so that it is unaffected by the full degree combinations when full degree combinations are registered in the full degree selector per Fig. 5. During the interval while the tenths of a degree selector is disabled a holding circuit maintains the proper tenth of a degree, that had been selected prior to the time the tenths of a degree selector was disabled so that, in effect, the proper tenth of a degree which is the tenth of a degree in the zero tenths zone or, more properly in this embodiment in the range from 95 to 04 hundredths of a degree, is maintained at the recording station while the proper code combination for the particular full degree is being impressed on the full degree selector per Fig. 5. How this condition is effected will be made apparent below. However, first the selecting paths which are controlled by relays 335 to 339 in both the tenths of a degree selector in the lower part of Fig. 4 and the full degree selector in Fig. 5 will be traced.

When the armature of relay 335 engages contact 348 a circuit may be traced from ground through contact 348, conductor 458 into Fig. 4 through the windings of relays 421A to 421E, conductor 510, into Fig. 5 and through the top winding of relay 520 to positive battery 525. When the armature of relay 336 engages contact 350 a circuit may be traced from ground 359 through contact 350, conductor 460 into Fig. 4, windings of relays 422A to 422C, conductor 509 into Fig. 5 and through the top winding of relay 521 to positive battery 525. When the armature of relay 337 engages contact 352 a circuit may be traced from ground 359 through contact 352, conductor 462 into Fig. 4, windings of relays 423A and 423B, conductor 508 into Fig. 5 and through the top winding of relay 522 to positive battery 525. When the armature of relay 338 engages contact 354 a circuit may be traced from ground 359 through contact 354, conductor 464 into Fig. 4, winding of relay 424A, conductor 507 into Fig. 5 and through the top winding of relay 523 to positive battery 525. When the armature of relay 339 engages contact 356 a circuit may be traced from ground 359 through contact 356, conductor 466, winding of relay 425A, conductor 506 into Fig. 5 and the top winding of relay 524 to positive battery 525. When the armature of relays 335 to 339 are actuated to engage their lower contacts 349, 351, 353, 355 and 359 respectively, positive battery 358 is connected to the originating end of each of these paths. The magnitude of the voltage of positive battery 358 is substantially greater than the magnitude of positive battery 325. Whenever ground 359 is connected to the above paths the armatures of the relays in the tenths selector in the lower part of Fig. 4 are actuated to the left. Whenever battery 358 is connected to the paths the armatures of relays in the tenths selector are actuated to the right. This is true whether the code combinations define tenths of a degree or full degrees. When tenths of a degree are defined the tenths of a degree selector responds by making a proper selection. When full degrees are defined, although the relays 421A, 421B, 421D, 421E, 422A, 422B, 422C, 423A, 423B, 424A, and 425A in the tenth of a degree selector respond, the response will not be effective to change the selection of the tenth of a degree in the range from 95 hundredths to 04 hundredths because relay 920 in Fig. 4 acts as a holding relay for the zero tenth degree zone in a manner to be described later.

When tenths of a degree code combinations are transmitted the selecting relays in Fig. 5 tend to respond but are locked in a manner to be described and cannot. When full degree codes are being transmitted the selecting relays in Fig. 5 are unlocked. At such times in response to the connection of ground 358 the armatures of selecting relays 520 to 524 are actuated to the left and when battery 358 is connected the armatures of relays 520 to 524 are actuated to the right.

*Operation of the tenths of a degree selector*

The top horizontal line in Fig. 13 shows the code combination for the selecting of the tenths of a degree lamp group from 95 to 04 in lamp bank 600 in Fig. 6. For this combination each of the rectangles representing a signal element in the five-element code is blank and the armatures of all of the relays in the tenths selector will be actuated to engage their right-hand contacts. The selecting path through the tenths selector extends through contact 429 of relay 802 and contact 426 of relay 402C. Regardless of the positions of these armatures the path which extends through contact 478, contact 474, contact 470 and contact 448 ends in an open circuit at contact 442. In the case of each of the other nine paths which extends through the tenths selector circuit, each of which will be traced hereunder, grounds 802 and 803 will be connected in parallel to the top terminal of some one of resistances 901 to 909 and to the inner terminal of a different one of nine different groups of ten lamps each in lamp bank 600. The armature of relay 920 is biased by a circuit which extends from battery 925 through the bottom winding of relay 920 to ground to engage contact 476 when the top winding of relay 920 is not energized. When any one of the nine continuous paths through the tenths selecting circuit is established the ground connected thereby to the corresponding one of the top terminals of resistances 901 to 909 meets battery connected to the right-hand terminal of the top winding of relay 920 and the armature of relay 920 will be actuated to the left. When the selecting path through the tenth selecting circuit for the tenth degree in the range from 95 to 04 is open and the armature of relay 920 engages contact 476 a circuit may be traced from ground 804 through the armature of relay 920, contact 476, conductor 499 into Fig. 6 to the inner terminal of the ten lamps in lamp group 95 to 04. Thus it should be apparent that the code combination of five no-current signal elements which is the combination for lamp group 95 to 04 results in an open selecting path through the tenth of a degree selecting relays and that for this condition the armature of relay 920, which is in engagement with contact 475 for all other of the nine possible tenth degree selections, will engage contact 476 to effect the selection of lamp group 95 to 04 which is called the zero tenths selection.

When any one of the nine other selecting paths through the tenths selector is closed, in a manner to be described, the armatuer of relay 920 will be operated to engage with contact 475. A circuit may then be traced from ground 804 through contact 475, bottom winding of relay 404B, bottom winding of relay 403B, bottom winding of relay 402C, conductor 511 into Fig. 5 and the top windings of relays 505, 504, 503, 502 and 501. When current flows in this path it is dominant over current flowing through the other winding of each of these relays when the paths through such windings are closed. In response to current of such polarity flowing through its bottom winding the armature of relay 404B will be actuated to the right. The armature of relay 403B will be actuated to the left. The armature of relay 402C will be actuated to the right. The armatures of relays 501 to 505 will be actuated to the left to lock the full degree selector in a manner to be described. The effect of the operation of the armature of relay 404B will be described below. The operation of the armature of relay 403B connects ground to one of the two branches at the apex of the tenths of a degree selecting circuit. The operation of the armature of relay 402C to the right connects ground to the other of the two branches at the apex of the tenths of a degree selecting circuit. Ground will thus remain connected through these two parallel branches which form the apex of the tenths selecting circuit during the entire interval while the observing instrument is in the range from 05 to 94 hundredths in each degree. At other times the armatures of relays 403B and 402C are under the influence of their respective top windings. These in turn are under the influence of the hundredths of a degree cams for a reason to be explained.

The second horizontal line in Fig. 13 shows the code combination for tenth of a degree lamps 05 to 14. For this condition, the armatures of relays 421A to 421E are actuated to the left. The armatures of other relays in the selecting paths in the tenths selecting circuit are actuated to the right. A circuit may then be traced from grounds 802 and 803 in parallel through contacts 429 and 426 in parallel, contact 478, contact 474, contact 470, contact 448, contact 441 and conductor 496 to parallel branches. One branch extends through resistance 903 and the top winding of relay 920. This operates the armature of relay 920 to engage contact 475 as explained above. The opening of contact 476 disconnects ground from conductor 499 which is connected to lamps 95—04. The second branch connects through conductor 495 to lamps 05—14.

It is emphasized that whenever grounds 802 and 803 are connected through a particular selecting path in the tenths selecting circuit to any one of the nine selecting conductors 490 to 498 to effect a selection of a particular group of ten lamps in lamp bank 600, a parallel path is established through some one of resistances 901 to 909 which connects to the top winding of relay 920. In each such instance, therefore, the armature of relay 920 will be disengaged from contact 476. Grounds 802 and 803 in parallel will be supplied for nine of the ten tenths selections of lamp bank 600 and ground 804 will be supplied for the tenth selection, namely, the selection of the tenths group 95—04.

The third horizontal division from the top in Fig. 13 indicates that the armatures of relays 421A to 421E and 422A to 422C are all actuated to the left and the armatures of the other relays in the selecting paths in the tenths selecting circuit are actuated to the right. A circuit may then be traced from grounds 802 and 803 in parallel through contacts 429 and 426 in parallel, contact 478, contact 474, contact 470, contact 447, contact 439 and conductor 494 which connects to the inner terminal of lamps 15—24.

The fourth horizontal division from the top in Fig. 13 indicates that the armatures of relays 422A to 422C are actuated to the left. The armatures of the other relays in the selecting paths in the tenths selecting circuit will be actuated to the right. A circuit may, therefore, be traced from grounds 802 and 803 in parallel through contacts 429 and 426 in parallel, contact 478, contact 474, contact 470, contact 447, contact 440 and conductor 495 which connects to the inner terminals of lamps 25—34.

The fifth horizontal division from the top in Fig. 13 indicates that the armatures of relays 422A to 422C and 423A and 423B will be actuated to the left. The armatures of the other relays in the selecting paths in the tenths circuit will be actuated to the right. A circuit may then be traced from grounds 802 and 803 in parallel through contacts 429 and 426 in parallel, contact 478, contact 474, contact 469, contact 445, contact 436 and conductor 491 which connects to the inner terminals of lamps 35—44.

The sixth horizontal division from the top in Fig. 13 indicates that the armatures of relays 421A to 421E, 422A to 422C, 423A and 423B are actuated to the left. The armatures of the other relays in the selecting paths for the tenths selector will be actuated to the right. A circuit may then be traced from grounds 802 and 803 in parallel through contacts 429 and 426 in parallel, contact 478, contact 474, contact 469, contact 445, contact 435 and conductor 490 which connects to the inner terminals of lamps 45—54.

The seventh horizontal division from the top in Fig. 13 indicates that the armatures of relays 421A to 421E, 423A and 423B will be actuated to the left. The armatures of the other relays in the selecting paths of the tenths selector will be actuated to the right. A circuit may, therefore, be traced from grounds 802 and 803 in parallel through contacts 429 and 426 in parallel, contact 478, contact 474, contact 469, contact 446, contact 437 and conductor 492 which connects to the inner terminals of lamps 55—64.

The eighth horizontal division from the top in Fig. 13 indicates that the armatures of relays 423A and 423B will be actuated to the left. The armatures of the other relays in the selecting paths of the tenths selector will be actuated to the right. A circuit may then be traced from grounds 802 and 803 through contacts 429 and 426 in parallel, contact 478, contact 474, contact 469, contact 446, contact 438 and conductor 493 which connects to the inner terminals of lamps 65—74.

The ninth horizontal division from the top in Fig. 13 indicates that the armatures of relays 423A, 423B and 424A will be actuated to the left. The armatures of the other relays in the selecting paths of the tenths selector will be actuated to the right. A circuit may then be traced from grounds 802 and 803 through contacts 429 and 426 in parallel, contact 478, contact 473, contact 468, contact 444, contact 471 and conductor 497 which connects to the inner terminals of lamps 75—84.

The bottom horizontal division in Fig. 13 indicates that the armature of relay 424A will be actuated to the left. The armatures of the other relays in the selecting paths of the tenths selector will be actuated to the right. A circuit may then be traced from grounds 802 and 803 in parallel through contacts 429 and 426 in parallel, contact 478, contact 473, contact 468, contact 444, contact 472 and conductor 498 which connects to the inner terminals of lamps 85—94.

It was shown that the one-hundredths selecting apparatus connected battery to the outer terminal of a particular lamp in each of the ten groups of lamps in lamp bank 600. A circuit to ground will be available at any one time in only one of the ten groups of ten lamps into which lamp bank 600 is divided and the one-hundredths selector and the tenths selector, therefore, cooperate to light a particular one of the one hundred lamps in lamp bank 600.

Reference to Fig. 14 shows the code combinations for the full degrees from 0 to 19 in each 20-degree zone. Each code combination for each of the twenty degrees as has been shown is impressed on the same side circuit which is used for the tenth of a degree selections during a portion of the interval while the tenths of a degree selecting circuit is selecting the tenth of a degree in the range from 95—04 at which time all of the tenths of a degree cam contacts are open. At this time, as has been explained, there is no continuous path through the tenths of a degree selector. The armature of relay 920, is, therefore actuated to the right and the tenths of a degree lamps in the range 95—04 are selected by relay 920 through contact 476. Reference to the right-hand vertical column of Fig. 14 which indicates the current and no-current condition for the 1105-cycle current as the fifth element of the five-element code shows that for sixteen of the twenty full degree selections, viz., from 4 to 19, inclusive, current of 1105 cycles is impressed on the line. For this condition the armature of relay 339 will be operated to close contact 356. Under this condition the armature of relay 425A will be actuated to the left to open contact 478. Ground will, therefore, be disconnected from each of the nine selecting paths which extend through contact 478. As a result of this, even though the various relays in the tenth of a degree selecting circuit respond to the full degree codes, there can be no continuous path for any of the nine selections which will pass through contact 478 and the lamp group from 95 to 04 will remain selected as contact 476 which connects ground 804 to conductor 499 remains closed.

Reference to the top four horizontal divisions in Fig. 15 corresponding to the codes for the full degrees from 0 to 3, in the first 20-degree zone and to corresponding full degrees in each of the other zones, inclusive, shows that for this condition the armature of relay 425 will be actuated to the right to close contact 478. However, for this condition, whatever the positions of the armatures of relays 402C and 403B, each of the paths through the tenths of a degree selector corresponding to each of these full degree codes extends to an open circuit notwithstanding the closure of contact 478. This will now be demonstrated.

Reference to the top horizontal division of Fig. 14 shows that for zero full degree the armatures of relays 422A to 422C and 424A will be actuated to the left. If ground is connected to the armature of relay 425A at such time, a circuit extends through contact 478 and contact 473 to open a circuit at contact 467.

In accordance with the code combination for full degree 1 the armatures of relays 421A to 421E, 422A to 422C, 423A, 423B and 424B will be actuated to close their left-hand contacts. The armature of relay 425A will be in engagement with contact 478. Even if ground is connected to the armature of relay 425A, a circuit extends through contact 478, contact 473 and contact 467 to an open circuit.

In accordance with the code for full degree 2, the armatures of relays 421A to 421E, 422A to

422C and 424A will be actuated to the left. The armatures of relays 423A, 423B and 425A will be actuated to the right. Whether or not ground is connected to the armature of relay 425A, a circuit extends through contact 478, contact 473 and contact 467 to an open circuit.

In accordance with the code for full degree 3 the armatures of relays 421A to 421E and 424A will be actuated to the left. The armatures of the other relays in the tenths of a degree circuit will be actuated to the right. Whether or not ground is connected at this time to the armature of relay 425A, a circuit extends through contact 478, contact 473 and contact 467 to an open circuit. From this it should be apparent that even though the code combinations for the full degree, which effect full degree selections by the control of relays in Fig. 5 in a manner to be explained, simultaneously operate the relays in the tenths of a degree selector in Fig. 4, the operation of the relays in Fig. 4 is ineffective. The tenth of a degree selection in the range from 95—04 is maintained by relay 920 as each of the selecting paths through the tenths of a degree selecting circuit terminates in an open circuit in response to the full degree codes.

*Operation of the full degree selector*

It was mentioned above that while nine of the ten tenths selecting paths for each degree are being selected, the armature of relay 920 is in engagement with its contact 475 and that during this interval current of a polarity to maintain the armature of relays 501 to 505 in engagement with their respective left-hand contacts is supplied to their top windings. This maintains relays 520 to 524 locked in a manner to be described. Relays 520 to 524 control full degree selections. The armatures of relays 501 to 505 are under control of two windings. The path through the lower windings of these relays was traced above in describing the operation of the hundredths selector. When the fourth element of the four-element code, which defines the hundredths degrees, is a current element, as indicated by a cross-hatched rectangle in the right-hand vertical column of Fig. 12, the armature of relays 334 engages contact 346. The path then extends from ground 359 through contact 346, conductor 456, winding of relay 404A, top winding of relay 404B and through the bottom windings of relays 505 to 501 to 65-volt battery 526. When the fourth element of the four-element code is a no-current element as indicated by a blank rectangle, the armature of relay 334 engages contact 347. Positive 130-volt battery 358 is then connected to this path.

When the armature of relay 334 is connected to ground 359, the effect of the current through the bottom windings of relays 501 to 505 tends to actuate their armatures to the right. When the armature of relay 334 is connected to battery 358, the effect of the current through the bottom windings of relays 501 to 505 tends to actuate their armatures to the left. Whenever contact 475 is closed, which is whenever the tenths of a degree selections other than zero tenths are made, the armatures of relays 501 to 505 will be under the dominant control of their top windings and their armatures will be actuated to the left to lock the full degree selector. Only during a portion of the time while the tenths of a degree selector is selecting the zero tenths path will the armatures of relays 501 to 505 be actuated to the right to unlock the full degree selector. Reference to the right-hand column of Fig. 12, which shows the current no-current conditions for the fourth element of the four-element hundredths of a degree code, shows that the fourth element is a current element only while digits 08, 09, 00 and 01 are being defined. As a result of this the armatures of relays 501 to 505 will be actuated to the right to unlock the full degree selector only while these digits are being selected in the zero tenths degree zone.

The paths through the bottom windings of the full degree selecting relays 520 to 524 have already been traced. While the 08, 09, 00 and 01 hundredths digits in the zero tenths zone are being defined, and only at such time, the armatures of relays 501 to 505 will be actuated to the right to open the locking paths through the top windings of relays 520 to 524. When the locking paths through the top windings of relays 520 to 524 are closed the effect of the current through the top windings is dominant over the effect of the current through their bottom windings and the armatures of relays 520 to 524 will be maintained in the position to which they were last operated. It is pointed out that code signal combinations defining tenths of a degree as well as full degrees are impressed on the bottom windings of the full degree selecting relays 520 to 524. But as long as the armatures of relays 501 to 505 remain in engagement with their left-hand contacts the armatures of relays 520 to 524 remain under control of their respective top or locking windings which lock the armatures in the positions to which they were last operated in accordance with the last full degree code combination received by relays 520 to 524.

When the measuring instrument first moves into the zero tenths of a degree zone in any degree, whether on increasing or decreasing measurements, all of the tenths of a degree cam contacts in Fig. 1, as has been explained, are opened. The continuous paths through the tenths of a degree selecting circuit, as has been shown, are immediately opened. If the movement of the measuring instrument progresses through the zero tenths zone toward 00 hundredths in either direction the full degree selector is unlocked to receive the full degree code combination. The code combination for the particular full degree will replace the code combination for zero tenths of a degree on the lower transmission circuit through the operation of switch 145. As has been shown, even though the relays in the tenths of a degree selector respond to the code signal combinations for the full degrees, the selection of zero tenths by relay 920 remains unaffected and the full degree signal code combination actuates the armatures of relays 520 to 524 to effect a full degree selection. As the movement of the measuring instrument continues, the setting of the armatures of relays 520 to 524 is locked. Switch 145 operates to disconnect the full degree code contacts. Then the zero tenths of a degree code combination is again impressed on the line for the remainder of the zero tenths of a degree interval.

The code combinations for full degrees shown in Fig. 14 are impressed on the bottom windings of relays 520 to 524. In response to a current signal element, as indicated by a cross-hatched rectangle in Fig. 14, the armature of the corresponding relay of the group 520 to 524 will be actuated to the left and in response to a no-current signal element, as indicated by a blank rectangle, the armature of the corresponding relay will be actuated to the right.

It will be assumed that the full degree selector is unlocked and that the signal code combination for nineteen full degrees, shown in the bottom horizontal division of Fig. 14, is impressed on relays 520 to 524. The code combination for nineteen full degrees indicates that only the fourth element, shown as a cross-hatched rectangle in the right-hand vertical column of Fig. 14, is a current element. In response to this the armature of relay 524 is actuated to the left. The armatures of relays 520 to 523 are actuated to the right. With the armature of relay 524 actuated to the left, a circuit may be traced from battery 527 through resistance 528, windings of relays 529 and 530, armature of relay 524 and contact 531 to ground. The contacts of relays 529 and 530 are operated upwardly as shown. The armatures of relays 531 to 538 will remain in their lower positions as shown. For this combination a circuit may be traced from battery, through lamp 539, contacts 540 to 544, conductor 513 into Fig. 4 and through contact 457 of relay 451 to ground. It will be assumed for the moment that the armature of relay 451 is in engagement with contact 457 pending explanation below. Lamp 539 which indicates an advance of the measuring instrument into the 19-degree position is lighted.

Before proceeding with the description of the full degree lamp circuit the locking circuit for relays 520 to 524 will be described.

It will be assumed that the measuring instrument moves either into the .02 degree position on increasing measurements or into the .97 degree position on decreasing measurements. Contact 475 has not closed because the measuring instrument is still in the zero tenths position. However, reference to the right-hand column of Fig. 12 indicates that the armature of relay 334 will be operated to engage its lower contact in either of these positions. In response to this, as has been explained, the armatures of relays 501 to 505 will be actuated to the left. With contact 531 of relay 524 closed a circuit may be traced from positive battery 527 through resistance 545 to parallel branches. One branch extends through resistance 546 to ground. The other branch extends through the armature of relay 501, contact 547, bottom winding of relay 524, armature of relay 524, and contact 531 to ground, locking the armature of relay 524 in its left-hand position.

In the case of a relay the armature of which has been operated to its right-hand position, of which relay 523 will serve as an illustration, the locking path may be traced from positive battery 548 through contact 549, armature of relay 523, bottom winding of relay 523, contact 550, armature of relay 502 and resistance 551 to ground. It will be observed that the locking paths for the two different positions of the armatures of relays 520 to 524 extends from positive battery through the bottom windings of the relays in opposite directions to ground.

When the measuring instrument moves out of the zero tenths zone in either direction, contact 475 of relay 920 closes, energizing the top windings of relays 501 to 505 which thereafter exercise the dominant control over their armatures, maintaining them in engagement with their left-hand or locking contacts, despite the changing effect of the current through the bottom windings of the relays while the measuring instrument is in the other nine-tenths of a degree in each degree.



*Control for measuring either increasing or decreasing quantities*

The system of the invention herein is arranged to measure and indicate either increasing or decreasing quantities. The mechanism which cooperates in performing this function will now be explained.

Attention is called to the fact that when the measuring instrument is in any 00 hundredth position it may be moved either forward into the position corresponding to the next higher full degree number or backward into the position corresponding to the next lower number. A single five-element full degree code combination is transmitted corresponding to the position of the full units cams when the measuring instrument is in the region of 00 hundredths. Whether the higher or lower numbered full degree indicator is selected will depend upon whether the movement of the measuring instrument is in a direction to increase or decrease the measured quantity. This is achieved by making a tentative selection of two indicators in response to each full degree code combination and a final selection through the cooperation of the hundredths of a degree selector depending upon whether the measured quantity is increasing or decreasing.

A circuit was traced above which extended from ground through contact 475, bottom windings of relays 404B, 403B, 402C, conductor 511 and through the top windings of relays 505 to 501 to positive battery. The effect of current flowing in this path through the bottom winding of relay 404B actuates the armature of relay 404B to the right. The purpose of this is to control the selecting mechanism for full degrees so that it will properly indicate the measurement of increasing or decreasing quantities.

During the interval while the nine-tenths of a degree, other than zero tenths, are being selected, when the armature of relay 920 engages contact 475 the effect of the current through the bottom winding of relay 404B is dominant and the armature of relay 404B will be maintained in engagement with its right-hand contact. The top winding of relay 404B responds to the effect of the fourth element of the four-element code for the hundredths of a degree shown in the right-hand vertical column of Fig. 12. During the selection of hundredths digits 08, 09, 00 and 01 only, while the zero tenths selection is being made, contact 433 of relay 404B is closed. A path then extends from ground through contact 423 to the armature of relay 401F from which point it may extend over either of two branches depending upon the position of the armature of relay 401F. The armature of relay 401F is under control of the first signal element of each four-element signal combination for hundredths of a degree as shown in the left-hand vertical column of Fig. 12. When the first signal element is a current element, as indicated by a cross-hatched rectangle in the left-hand vertical column of Fig. 12, the armature of relay 401F, as has been explained, will be actuated to the left and when the first element is a no-current element, as indicated by a blank rectangle, the armature will be actuated to the right.

Let it be assumed that the armature of relay 401F is actuated to the left as shown. The circuit then extends through contact 415, bottom winding of relay 451 and resistance 455 to positive battery 465. The effect of this current actuates the armature of relay 451 to the left as shown to close contact 457. When the armature of relay 401F is actuated to the right in response to a no-current signal element as the first element of the four-element signal code, the path extends through contact 416, top winding of relay 451 and resistance 453 to positive battery operating the armature of relay 451 to the right to close contact 459. When the armature of relay 451 engages contact 457 it locks in this position over a circuit from ground through the armature and contact 457 of relay 451, resistance 463, bottom winding of relay 451 and resistance 455 to positive battery 465. When the armature of relay 451 engages contact 459 it locks in this position over a circuit from ground through the armature and contact 459 of relay 451, resistance 461, top winding of relay 451 and resistance 453 to positive battery 465. The effect of the operating current in each instance is dominant over the effect of the locking current so that the armature of relay 453 may respond to the controlling first signal elements of the four-element hundredths of a degree code combination.

When the path for the 19 "advance" lamp was traced it was shown to extend through conductor 513 and contact 457 to ground. Conductor 513 is shown connected in parallel to three armatures of relay 530. Three branch paths are shown extending from the armatures of relay 530 through the contacts of relays 531, 533, 535 and 537 to three "advance" lamps. Conductor 512 is shown connected to three armatures of relay 529 and three branch paths are shown extending from the armatures of relay 529 through the armatures of relays 532, 534, 536, 538 to three retrogress lamps. There are actually twenty sets of armatures on each of relays 529 to 538. There are twenty paths through each of the two groups of relays into which these relays are divided. The paths actually shown will exemplify the invention as it is well known in the art that armatures on a set of five relays can be arranged in response to five-element two-condition signals to provide a total of thirty-two selecting paths of which only twenty in each group are employed in the arrangement herein.

Each of the twenty full degree code combinations establishes two separate paths which are continuous through the contacts of the two separate groups of five relays. Only one of the total of forty paths will be closed to ground through the armature of relay 451 at any one time. One of each of the pairs of paths extends through a lamp to define the full degree position when the measuring instrument advances into it through 00 hundredths. The other defines the full degree position when the measuring instrument retrogresses into it through 00 hundredths. The same code combination therefore defines, for example, the 19 advance position and the 18 retrogress position of the instrument. Which of the two selections is completed depends upon the direction in which the instrument is moving.

Refer now to the left-hand and right-hand vertical columns of Fig. 12 which show the current and no-current conditions of the first and fourth elements of the four-element code for the hundredths of a degree selections. Let it be assumed that the measuring instrument is in some .95 of a degree position and that the measured angle is increasing. Contact 745 of relay 920 is open to unlock relay 404B. The armature of relay 451 is locked in the position to which it was last operated to maintain the last selection. Since the code combinations for 95, 96 and 97 hundredths specify a no-current condition for the fourth element of the four-element code per Fig. 12 the armature of relay 404B will remain in engagement with its contact 434 during these selections. In response to the current condition of the fourth element of the code combination for 98 hundredths, the armature of relay 404B will be actuated to close contact 433. Reference to the left-hand column of Fig. 12 shows that the first element of the four-element code is a no-current element throughout the interval from 95 to 99 hundredths. In response to the no-current signal element the armature of relay 401F will be in engagement with contact 416. As a result of this the armature of relay 451 will be operated to engage its contact 459 during the 98 and 99 hundredths of a degree selection. When the measuring instrument moves into the 00 hundredths of a degree position, however, the first signal element of the code combination is a current signal element. In response to this the armature of relay 401F will be actuated to close contact 415. This closes contact 457. The closing of contact 457 will effect a selection of the advance lamp corresponding to the code combination for the particular full degree. The fourth element of the four-element code combination remains a current element for the 98, 99, 00 and 01 code combinations. The armature of relay 404B remains in engagement with its contact 423 during this interval. For the 02 hundredth combination the fourth signal element of the hundredths of degree combination is a no-current signal element and the armature of relay 404B is disconnected from contact 433 so that ground is no longer connected to the circuit which controls relay 451. The first element of the four-element code remains a current element for each of the code combinations from 00 hundredths to 09 hundredths so that the armature of relay 401F remains in engagement with contact 415 from the time it engages contact 415 until after ground is disconnected through the operation of the armature of relay 404B to engage contact 434. Once contact 433 opens the armature of relay 451 will be locked in engagement with contact 457 to maintain the selected advance full degree lamp lighted as the measured quantity continues to increase.

In the case of the measurement of a decreasing quantity reference to the left-hand and right-hand vertical columns in Fig. 12 shows and the foregoing description indicates that the armature of relay 401F will be in engagement with contact 415 when contact 433 of relay 404B is closed for the 01 hundredth of a degree selection. For the 01 and 00 hundredths of a degree selection the armature of relay 451 will engage contact 457. For the 99 hundredth of a degree selection, since the first element as shown in the left-hand vertical column is a no-current element, contact 416 of relay 401F will be closed. In response to this contact 459 of relay 451 will be closed to light the retrogress lamp which has been selected. The armature of relay 401F will remain in engagement with contact 416 until after contact 433 is opened at the 97 hundredths degree position to maintain control of relay 451. When contact 433 is opened the armature of relay 451 will be locked in engagement with the locking circuit to maintain the retrogress selection.

Figs. 9, 10 and 11 show the developed peripheries of the full degree, tenths of a degree and hundredths of a degree cams respectively. The developed periphery of switching cams 125 is shown at the top of Fig. 10.

What is claimed is:

1. In a data transmission system, a first transmission circuit, a plurality of means in said circuit for simultaneously transmitting a plurality of alternating currents of different frequencies in accordance with a first multielement permutation code combination, a second transmission circuit, a plurality of means in said second circuit for simultaneously transmitting a plurality of alternating currents of different frequencies in accordance with a second multielement permutation code combination, a single measuring instrument connected to said circuits at an observing station for controlling the transmission of all of said currents and means connected to said circuits at a receiving station for selecting any one of a hundred indicators in response to the simultaneous reception of said currents from each of said circuits.

2. In a data transmission system, a transmission circuit, five separate independent alternating current conducting channels in said circuit corresponding to five elements of a permutation code, means connected to said circuit for translating any numeral in one place in a multidigit number into alternating current signal elements in accordance with combinations in said five-element code requiring for transmission changes in the conditions of four of said channels only while said fifth channel remains unchanged in one of two possible conditions and means for translating combined digits in two other places in said number into single code combinations requiring changes in the conditions of all of said five channels.

3. In a data transmission system, an observing station, a receiving station, a first transmission circuit interconnecting said stations, a plurality of separate channels each individual to alternating current of a corresponding plurality of different frequencies in said circuit, means for impressing on said circuit combinations of signal elements of said different frequencies in accordance with a first permutation code to identify a digit in one position in a multidigit number, a second transmission circuit connecting said stations, a plurality of separate channels each individual to alternating current of a corresponding plurality of different frequencies in said second circuit, means for impressing on said second circuit combinations of signal elements of said different frequencies in accordance with a second permutation code to identify digits in two other positions in said multidigit number and a single signal element control means at said observing station for controlling the impressing of successive code combinations of signals on both of said channels to identify multidigit numbers in an ordered sequence.

4. In a data transmission system, an observing station, a receiving station, a source of alternating current of a single frequency at said receiving station, means interconnecting said stations for transmitting said current to said observing station, means at said observing station responsive to the reception of said current for translating said current into currents of at least four frequencies and permutatively adjustable means at said observing station for selecting permutation code combinations of said frequencies to define measurements at said observing station.

5. In a data transmission system, an observing station, a receiving station, a transmission circuit interconnecting said stations, a source of alternating current of a single frequency at said receiving station, means for transmitting said current to said observing station, means at said observing station for translating said current into current of at least four frequencies, and permutatively adjustable means at said observing station for selecting simultaneously a plurality of permutation code combinations of said frequencies to define simultaneously different portions of a multidigit number corresponding to a measurement at said observing station.

6. In a data transmission system, instrumentalities for transmitting alternating current of a single frequency from a receiving station to an observing station, means for translating said current into current of at least four frequencies at said observing station, means for establishing permutative adjustments to select permutation code combinations of currents of said frequencies at said observing station to define measurements, means for retransmitting said selected currents to said receiving station to indicate said measurements.

7. In a data transmission system, instrumentalities for transmitting alternating current of a single frequency from an indicating station to a measuring station, means for translating said current, at said measuring station, into alternating currents of a plurality of frequencies, means for selecting from said currents a plurality of permutation code combinations of currents of different frequencies to define separate portions of a multidigit number corresponding to a measurement, and means for retransmitting said current combinations to said indicating station.

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