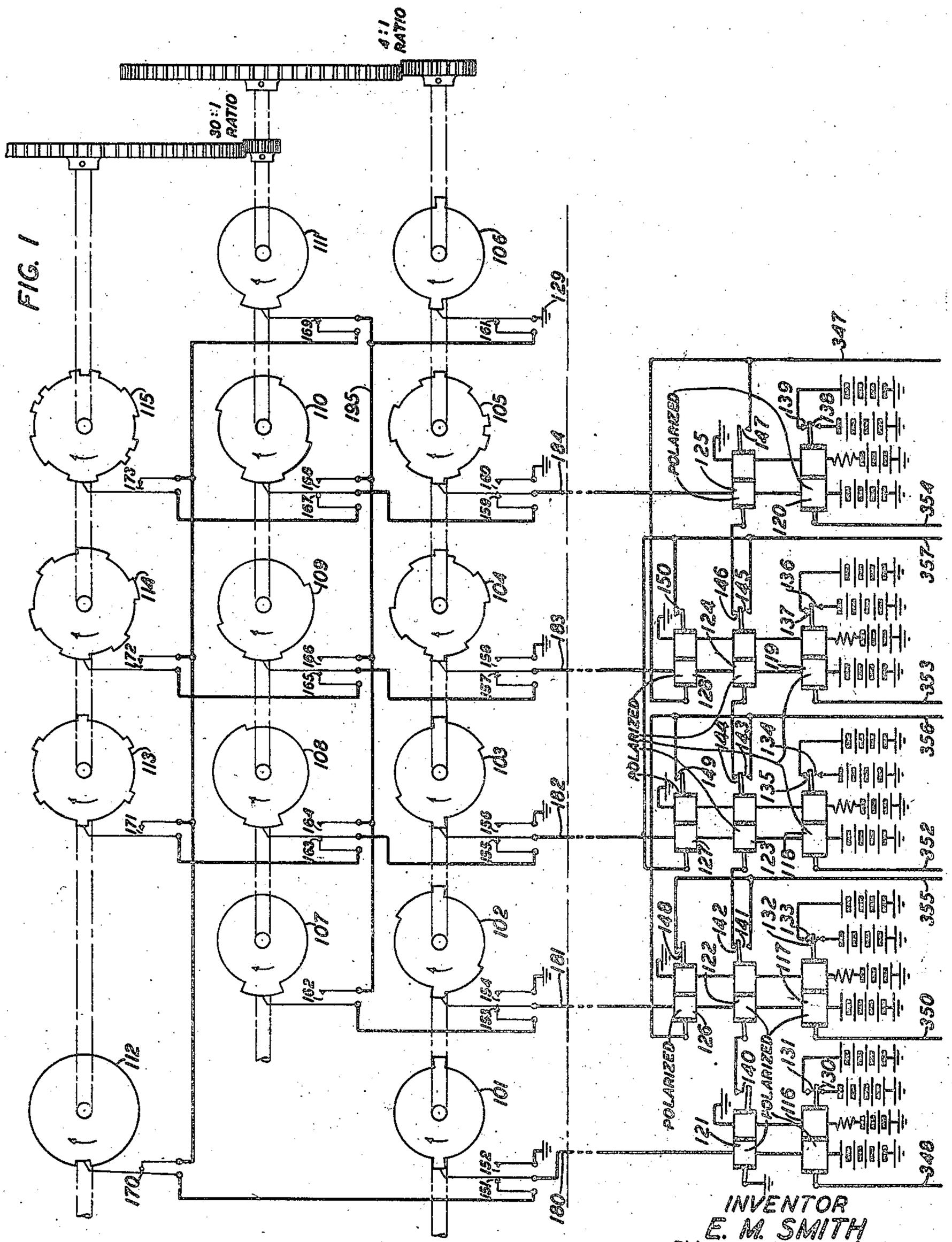
Aug. 13, 1946. E. M. SMITH 2,405,618

PERMUTATION CODE DATA TRANSMISSION SYSTEM

Filed May 12, 1943 5 Sheets-Sheet 1

FIG. 1



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PERMUTATION CODE DATA TRANSMISSION SYSTEM

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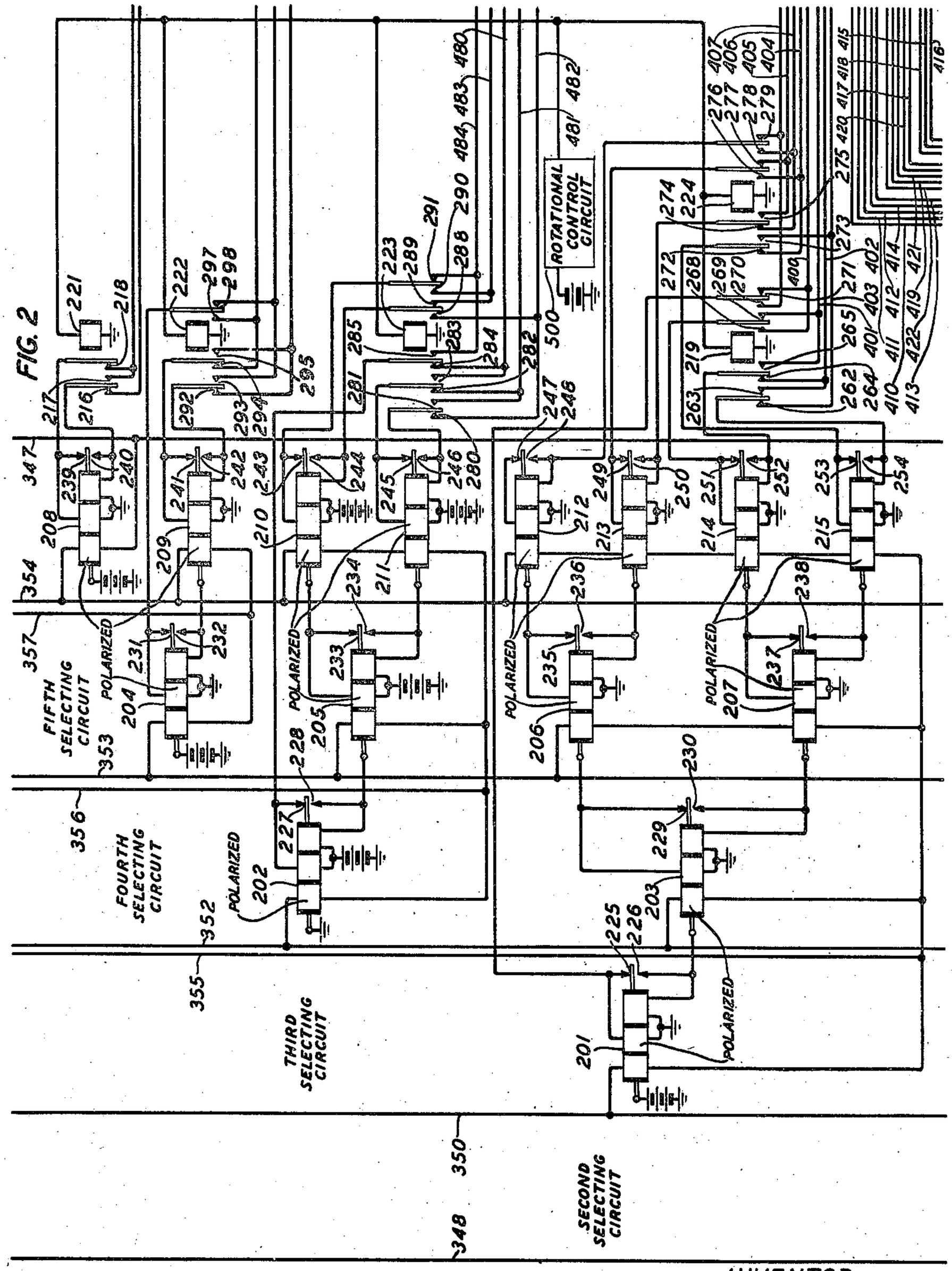
FIG. 2



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PERMUTATION CODE DATA TRANSMISSION SYSTEM

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FIG. 3

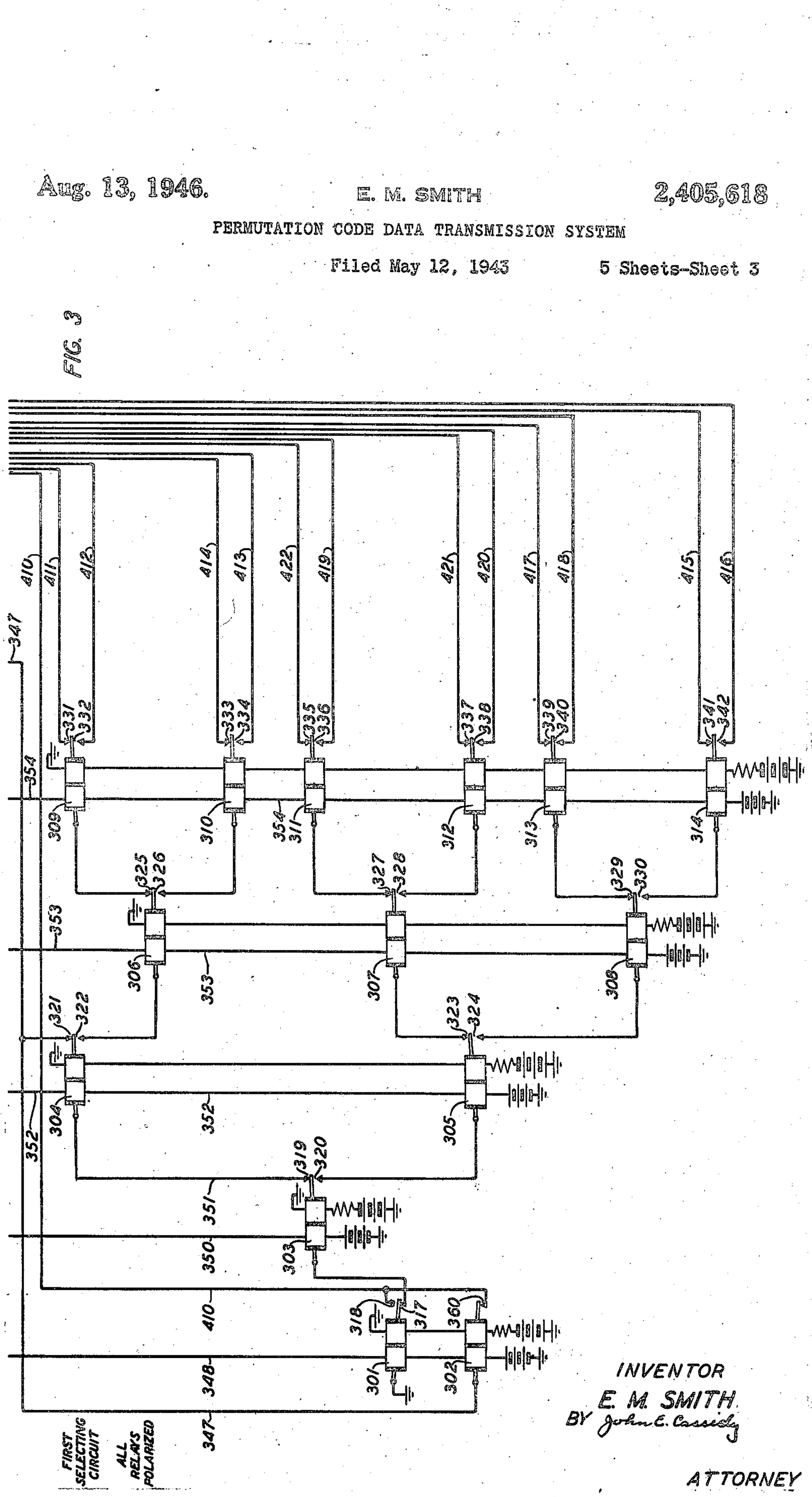

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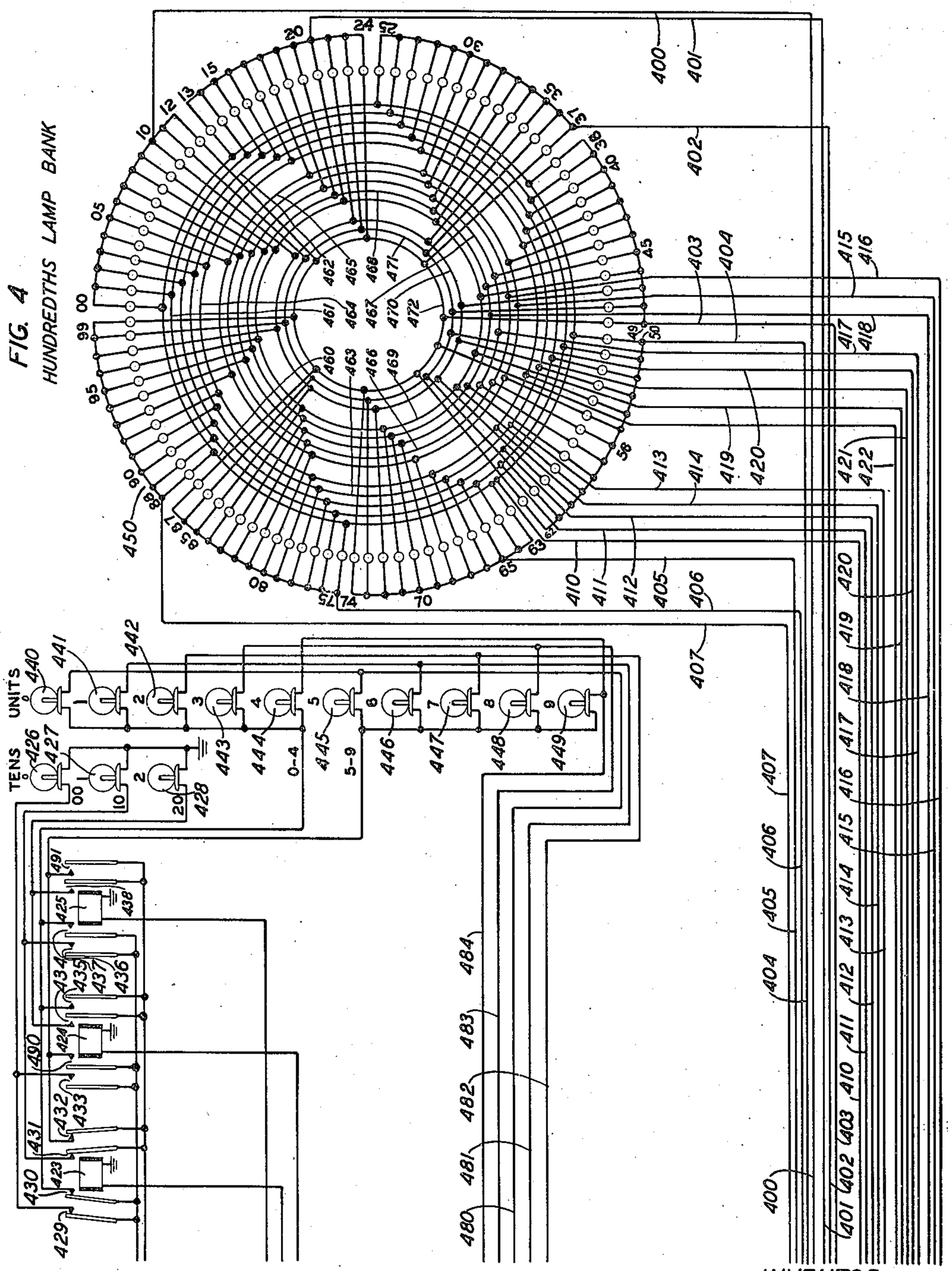
FIG. 4

HUNDREDTHS LAMP BANK



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PERMUTATION CODE DATA TRANSMISSION SYSTEM

Filed May 12, 1943 5 Sheets-Sheet 5

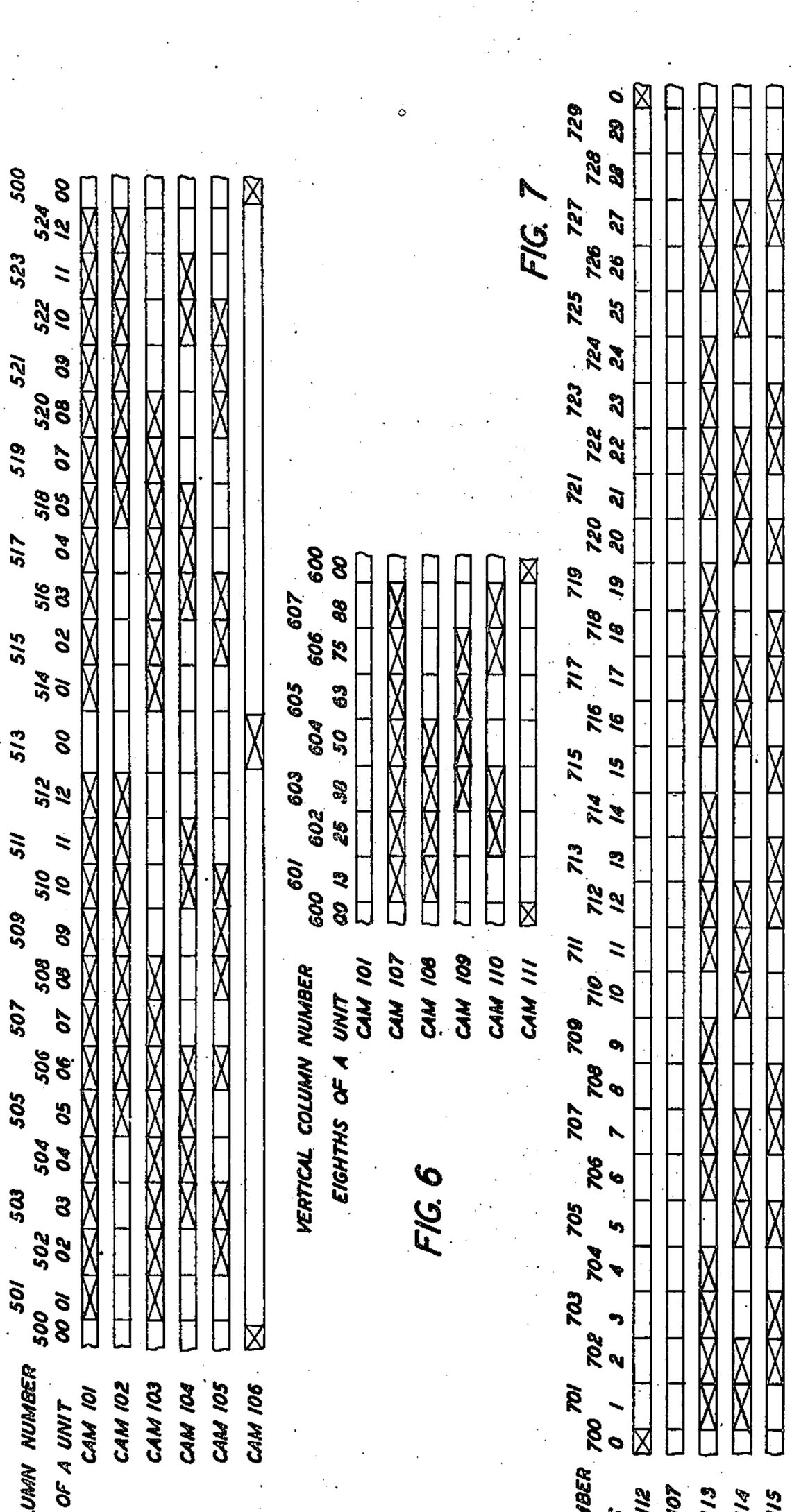

FIG. 5

FIG. 6

FIG. 7

FIG. 1	
FIG. 2	FIG. 4
FIG. 3	

FIG. 8

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UNITED STATES PATENT OFFICE

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PERMUTATION CODE DATA TRANSMISSION SYSTEM

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Application May 12, 1943, Serial No. 486,652

5 Claims. (Cl. 177—353)

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This invention pertains to high speed permutation code signal data transmission systems and to telemetering systems.

More particularly this invention is an improved permutation code signal data transmission system or telemetering system requiring a minimum of conductors or transmission channels interconnecting the data measuring station and receiving station for designating any of 3,000 observations or measurements almost instantly.

By means of the data transmission or telemetering system of this invention only five conductors or transmission channels are required to interconnect the observing and receiving stations to define almost instantly any of 3,000 observations.

The invention may be employed to define any measured quantity where the quantities to be measured are progressively increased. In this present embodiment the invention is arranged to cover a range of 3,000 observations or measurements. It is assumed that the quantity measured extends over a range from zero units to thirty units and the system defines the measurement to the nearest hundredth of a unit. The system may be employed to transmit permutation code signals defining the readings of measuring meters used for any purpose.

A feature of this invention is an arrangement for impressing permutation code signals which completely define a number having four digits on a single five-channel telegraph signal circuit at the same instant.

A further feature of this invention is the employment at the receiving station of five separate relay selecting circuits for the translation of the permutation code signals defining the digits in the different places in a multidigit number corresponding to observed or measured data which selecting circuits are controlled simultaneously by a single five-channel permutation code transmission circuit common to all five selecting circuits.

A further feature of this invention is an arrangement for impressing permutation code signals which completely define a number having four digits on a single five-channel telegraph signal circuit at the same instant and thereafter impressing said signals on five separate independent selecting circuits.

A further feature of this invention is an arrangement for impressing each of the five elements of a five-element permutation code signal individually through a separate one of five transmission channels on five separate selecting circuits simultaneously, each of said selecting circuits being capable of making an independent selection and all selections cooperating to define the separate digits of a four-digit number simultaneously.

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A further feature of this invention is an arrangement of five separate selecting circuits controlled by five transmission channels serving said circuits in common, which arrangement includes means for impressing permutations of two electrical conditions from each of the five channels on the first of the selecting circuits to indicate the setting of a measuring instrument to the nearest hundredth of a unit in each of eight zones into which the full unit is divided, which arrangement includes also means for controlling the first selecting circuit at times by means of one of the five channels only so that it indicates the first hundredth of a unit setting of a measuring instrument in each of the eight zones at such times in response to a condition impressed on it by the one channel, while a second selecting circuit is controlled by means of conditions impressed on it by the other four channels to indicate the particular one of the eight zones in which the measuring instrument is set.

A further feature of this invention is an arrangement for maintaining four of five selecting circuits in a particular fixed condition in response to an electrical condition impressed on each of four out of five transmission channels to completely define three of the digits in a four-digit number while the fifth selecting circuit is controlled by an electrical condition impressed on the fifth channel only to determine the digit in the fourth position of the number.

General description

In the present invention it is assumed that any quantity in a thirty-unit range is measured to the nearest hundredth of a unit. The measurements are translated into various code combinations of settings of three sets of cams. One set of cams establishes twenty-five permutation code settings of a group of contacts to define the twenty-five different hundredths of a unit setting in each quarter unit. A second set of cams establishes eight permutation code settings to define the eight zones in each unit. The eight zones are not equal. Four of them, as will be further explained, each contain thirteen hundredths of a unit and the remaining four each contain twelve hundredths of a unit. For convenience herein these will be called eighths of a unit. A third set of cams establishes permutation code settings

to define units, groups of five units and groups of fifteen units. The cams control contacts each of which is arranged to impress either of two electrical conditions on a corresponding one of five conductors or transmitting channels connecting the measuring instrument located at an outlying observing or measuring station to receiving, selecting and indicating apparatus at a central receiving or metering station. The permutation code signals are impressed on five sets of polar receiving relays which are operated in a manner to correspond to the code. The polar receiving relays are in turn connected within the receiving station to five separate selecting circuits by means of five local transmission channels. The five selecting circuits are controlled simultaneously by the five channels.

The selecting circuits are arranged in the general form of fan relay circuits modified per this invention, so that, in addition to the usual selections made by the cooperation of the various relays in each fan circuit under the influence of a number of transmission channels, the relay at the apex of the fan in each selecting circuit may at times make a single selection in response to an electrical condition impressed on one channel only, while the selection remains unaffected by the conditions impressed on the other channels.

By this expedient it is possible to make a selection in each of a number of selecting circuits to define particular digits, such as the zero digits for example, in certain places of the number, while another selecting circuit responds simutlaneously to permutation code signals impressed on less than five of the channels to indicate a digit in a higher valued place in the number.

The selecting circuits cooperate to light four numbered lamps to indicate the four digits corresponding to the setting of the measuring instrument, thus identifying the measured quantity within the thirty-unit range to the nearest hundredth of a unit.

The speed of operation of the apparatus of the invention herein compares favorably with the speed of operation of data transmission apparatus or telemetering apparatus operating on the voltage or resistance balancing methods of operation. The number of transmission channels required is the minimum for a permutation code signal transmission system capable of as many selections.

Thus advantage may be taken of the desirable characteristics of a telegraph permutation code signaling system, namely, that it is not subject to errors due to variation in the impedance of the channels caused by variations in temperature and variations in leakance due to weather changes which affect other types of such systems and this may be achieved with little, if any, appreciable sacrifice in speed and by employing a minimum of transmission channels connecting the stations.

It has been explained that permutation code signals set up on the cams at the observing or measuring station are impressed on five transmission channels to operate five sets of polar receiving relays at the receiving station. Five of the polar relays, one in each set, impress the permutation code signals by means of five local channels within the receiving station on the selecting circuits. All five of the transmission channels interconnecting the polar receiving relays and the selecting circuits are connected to one of the five selecting circuits only. Four of these five transmission channels are connected to a second selecting circuit; three of them are connected also to a third selecting circuit; two to a fourth selecting circuit and one to a fifth selecting circuit.

In the first selecting circuit there are five switches for changing the selecting paths through the circuit. In the second selecting circuit there are four switches for this purpose. In the third, second and first selecting circuits there are three, two and one switch, respectively. A permutation code signal containing five signal elements is impressed on the channels to the five selecting circuits simultaneously. If a change is required in a digit in the first right-hand position of the number only or in the first two positions for a change within the same eighth of a unit zone, only one selecting circuit, namely, the one having five switches, will respond while the other four selecting circuits remain locked. If a change is required in a digit in the second right-hand position in the number corresponding to a change between eighth of a unit zones and no change is required in a digit in any higher valued position of the number, the second selecting circuit is arranged to respond to four elements of the five-unit code, while the third, fourth and fifth selecting circuits remain locked. Since each such transition involves also a change in the right-hand digit of the number, such a transition will be made by the fifth selecting circuit under control of one of the five channels only. In general the various selecting circuits are arranged in cascade so that when changes are required in higher valued positions in the number, a fewer number of transmission channels control a selecting fan circuit with a correspondingly fewer number of switches to effect the transition while an electrical condition impressed on single channels, not employed in effecting the transition in the digit in the higher valued position of the number, effects a transition in each selecting fan circuit for each lower valued digit involved.

At all times five-element permutation code signals are being transmitted by the cam controlled contacts at the receiving station and retransmitted by the corresponding five polar receiving relays at the receiving station. All five elements are employed at times in setting the switches of the hundredths of a unit selector only to indicate the measuring instrument setting within each eighth divisions of a unit to the nearest hundredth of a unit. At such times the selectors for the higher valued settings are locked in the last position in which they were set. At other times as determined by the value of the measured quantity, the conditions of four elements of the five-element code will set the eighth of a unit selector to indicate the eighth of a unit settings. At such times one switch in the selector for the hundredths of a unit within each eighth of a unit will be controlled by the electrical condition of the fifth element of the code only to select the lowest value hundredth of a unit in each eighth of a unit zone while the selectors for the higher valued digits will be locked in the last position in which they were set. At other times, as required, the electrical condition of three elements of the five element code will set the switches in the selector for the indicator defining the digit in the units position or the first position to the left of the decimal point. A single switch of the four switches in the selector for the eighth of a unit selection will meanwhile be set by the electrical condition impressed on one channel only to select all thirteen indicators in the first eighth of a unit zone. A single switch of the five switches

in the selector for the hundredths of a unit selection within each eighth of a unit zone will meanwhile be set by the electrical condition impressed on another single channel to select one of these thirteen indicators, namely, the zero indicator for the hundredths of a unit selection while the transition is made. The selectors for the digits of the number higher in value than the units digit will be locked meanwhile in the last position in which they were set. The same general procedure is followed for the selection of a lamp indicating the digit in the tens position or the second place to the left of the decimal.

The invention may be understood from the following description when read with reference to the associated drawings in which:

Fig. 1 shows three sets of cams arranged in horizontal rows. The cams are assumed to be controlled by a measuring instrument, not shown, at the transmitting station. The cams control electrical contacts which set up and transmit permutation code signals over five electrical transmission channels connecting the observing or measuring station to the receiving station where they are impressed on five sets of polar relays, the armatures of which are set in accordance with the code in response to the received signals. The receiving relays impress the received code signals on five selecting circuits per Figs. 2 and 3.

Fig. 2 shows the upper portion and Fig. 3 the lower portion of a selecting system comprising five separate relay selecting circuits resembling fan circuits which respond to the code signals retransmitted from the polar receiving relays in Fig. 1 to translate the codes received by them from the cams into lamp selections in the indicator circuit per Fig. 4.

Fig. 4 is an indicator circuit comprising essentially a bank of one hundred lamps, shown at the right, which indicates the setting of the measuring instrument to the nearest hundredth of a unit. The figure shows also a bank of ten lamps arranged in a vertical row which correspond to the numeral in the units position or in the first position to the left of the decimal point. To the left of the group of ten vertical lamps is a group of three lamps arranged also in a vertical row which correspond to the numeral in the tens place or in the second position to the left of the decimal point. Only 3,000 selections are made by the system of the invention in its present form so only three lamps are required for the tens digit. It is to be understood, however, that the system of the invention is capable of unlimited expansion and is not limited to the definition of 3,000 measurements only.

Fig. 5 is a chart showing the permutation code signals set up by the bottom row of cams, cams 101 to 105, in Fig. 1 during a revolution to define the digit in the right-hand position of the number which in this case corresponds to the hundredth of a unit setting of the measuring instrument and shows also the relative times at which cam 106 connects ground through to the second horizontal row of cams so that codes defining the digits in the higher valued positions in the number may be transmitted as required.

Fig. 6 is a chart showing the permutation code signals set up by cams 101 and 107 to 110 in Fig. 1 to define the digit in the second right-hand position which in this case corresponds to the eighth of a unit setting of the measuring instrument and shows also the relative times at which cam 111 connects ground through to the top horizontal row of cams for transmitting codes defining the digit in the two left-hand positions of the number when required.

Fig. 7 is a chart showing the permutation code signals set up by cams 112, 107 and 113 to 115 in Fig. 1 during a revolution to define the digits in the two left-hand positions of a number corresponding to a measurement which in this case corresponds to the digits in the units and tens position in the number or in the first and second positions to the left of the decimal point.

Fig. 8 is a diagram showing the manner in which Figs. 1, 2, 3 and 4 should be arranged, each in relation to the other to form an operative system.

Detailed description

Refer now to Fig. 1. Cams 101 to 106 are rigidly secured to a first shaft, cams 107 to 111 to a second shaft and cams 112 to 115 to a third shaft. As the measuring instrument, not shown, is rotated, the three shafts which are connected to the measuring instrument by the gear system in any convenient manner are rotated to maintain the following relationship. As the measuring instrument changes through the full thirty-unit range cams 112 to 115 turn through one revolution. As the measuring instrument changes through a range of one full unit, cams 107 to 111 turn through one revolution.

Cams 113 to 115 are so arranged that as they rotate through a complete revolution they set up thirty permutations of contacts 170 to 173 to define each of the thirty full units. The peripheries of cams 112 to 115 are arranged in two levels. Where the periphery of the cam is raised the corresponding contact is open. Where the periphery of the cam is depressed the corresponding contact is closed. Cams 107 to 110 are arranged so that as they rotate they operate their respective contacts to set up eight different permutations of open and closed circuit conditions to define eight different eighths of a unit changes in setting of the measuring instrument within each unit. Cam 111 is a ground supply switching cam employed to supply ground at the proper intervals to the top row of cams.

The peripheries of cams 107 and 111 each have two levels. Where the periphery of cam 107 is raised, contact 162 is open and where it is normal contact 162 is closed. Where the periphery of cam 111 is normal contact 169 is open and where it is raised contact 169 is closed. The peripheries of cams 108, 109 and 110 each have three levels. At their highest level these cams close their respective contacts 163, 165 and 167. Where the peripheries of cams 108, 109 and 110 are normal their respective contacts 163 to 168 are all open. Where the peripheries of cams 108, 109 and 110 are depressed, their corresponding contacts 164, 166 and 168 are closed.

As cams 101 to 105 rotate through one revolution they set up twenty-five permutations of open and closed circuits conditions to define each one of the twenty-five different hundredths of a unit settings of the measuring instrument within each quarter of a unit. The twenty-five codes which are set up are not all different, however. For each of the first thirteen of the twenty-five positions, thirteen different permutation codes are transmitted to define thirteen different hundredths of a unit settings of the measuring instrument. Then twelve of these codes are repeated to define the remaining twelve different hundredths of a unit settings of the measuring instrument in each quarter of a unit. Reference to Fig. 5 shows that in repeating the codes, the

code defining the sixth hundredth of a unit setting in the first half revolution of cams 101 to 105 is not repeated in the second half revolution of these cams. Cam 106 is a ground supply switching cam for the two upper rows of cams.

The peripheries of cams 101 and 106 are arranged in two levels. Where the periphery of cam 101 is raised contact 151 is closed and where it is normal contact 152 is closed. Where the periphery of cam 106 is raised, contact 161 is closed and where it is normal, contact 161 is open. The peripheries of cams 102 to 105 are arranged in three levels. The raised level closes contacts 153, 155, 157 and 159. At the normal level of the peripheries of cams 102 to 105 all of the corresponding contacts are open. Where the peripheries of cams 102 to 105 are depressed contacts 154, 156, 158 and 160 are closed.

Refer to Figs. 5, 6 and 7. In Fig. 5 there are five horizontal rows of cross-hatched and blank rectangles corresponding to the open and closed circuit conditions of the right-hand contacts associated with cams 101 to 105, respectively and the left-hand contact of cam 106. In Fig. 5 there are also twenty-five vertical columns numbered 500 to 524. Each vertical column represents a combination of open and closed contact conditions of contacts 152, 154, 156, 158 and 160 controlled by cams 101 to 105, respectively. Reference to vertical column 500 indicates that five of the rectangles in the vertical row corresponding to cams 101 to 105 are blank, while the rectangle corresponding to cam 106 is cross-hatched. The blank condition of the rectangles corresponding to cams 101 to 105 indicates that their associated right-hand contacts 152, 154, 156, 158 and 160 are open to form the permutation code for the .00 unit position. In this position cam 106 closes its corresponding contact 161 to connect ground to the upper horizontal row of cams. This is indicated by the fact that horizontal row 106 is cross-hatched in vertical row 500.

The cross-hatched and blank rectangles in vertical row 501 in Fig. 5 indicates that contacts 152 associated with cam 101 and 156 associated with cam 103 are closed and contacts 154, 158 and 160 associated with cams 102, 104 and 106, respectively, are open to form the permutation code for the .01 unit. Vertical columns 502 to 524 show the codes for the other twenty-three positions in each quarter of a unit set up during a revolution of the bottom horizontal row of cams.

In Fig. 6 there are seven horizontal rows corresponding to cams 101 and 107 to 111 and eight vertical rows numbered 600 to 607 corresponding to the eight divisions of the peripheries of these cams. The permutation codes for each of the eight unit divisions are indicated in the eight vertical rows of the top five horizontal rows. The horizontal row corresponding to cam 111 indicates that contact 169 is closed to supply ground to the top horizontal row of cams while the code corresponding to the first eighth of a unit division, or more exactly for the zone from .00 to .13, is being transmitted by the middle row of cams.

Fig. 7 shows five horizontal rows one for each of cams 112 to 115, inclusive and thirty vertical rows to define the codes for each of the thirty full unit settings.

Five conductors 180 to 184 connect the code cams at the measuring station to the polar receiving relays at the receiving station. It is pointed out that, in place of the five conductors, alternating current channels which may be five carrier current channels may be employed. The carrier current channels may be impressed on a single metallic circuit or on a radio link interconnecting the stations.

Before proceeding with the explanation of the detailed operation of the circuit it is pointed out that, in general, in transmitting the code signals from any of the contacts controlled by the cams, for one condition the electrical circuit interconnecting the cams and the receiving relays is grounded at the measuring station and for the other condition the circuit is open. When any circuit is grounded the armatures of the corresponding polar receiving relays at the receiving station are operated to their respective lower positions. When the transmitting channel is open the armatures of these relays are actuated upwardly due to the effect of current in their biasing windings. Five-element two-condition permutation code signals are transmitted in every instance. The armatures of each of the relays connected to channels 180 to 184 are set in either of their two positions in response to the code signals.

In response to the five-element code signals from the cam controlled contacts either positive or negative battery is impressed through the armatures of the five relays 116 to 120 on the selecting circuits.

As heretofore mentioned, there are five separate selecting circuits. All five of the five-element signals are not impressed on each of the selecting circuits. Reference to Figs. 1, 2 and 3 shows that the armatures of all five code receiving relays 116 to 120 are connected only to the first selecting circuit shown in Fig. 3.

While codes defining the hundredths of a unit are being transmitted, all five of the sets of relay switches in the first selecting circuit are set in position. The selections in the other four selecting circuits are maintained due to locking arrangements in the circuits while the hundredth codes are being transmitted into the first selecting circuit. When the setting of the measuring instrument involves the transmission of codes requiring a new selection by the second selecting circuit, the second selecting circuit is conditioned to respond. Only four of the five elements of the five-unit code are impressed on the four switches in the second selecting circuit at such times. The fifth element of the code sets the switch nearest the apex of the first selecting circuit simultaneously to effect a selection by a single switch only in the first selecting circuit at such time.

When the measured data involves a change in a selection by the third selecting circuit and no change in the fourth and fifth selecting circuits, the selections last made by the fourth and fifth selecting circuits are maintained by locking arrangements in the circuits. Three signal elements of the five-unit code are impressed on the third selecting circuit to set three relay switches therein. The fourth signal element is impressed on the second selecting circuit only and a fifth signal element is impressed on the first selecting circuit only. In the first and second selecting circuits the single signal element sets one switch only in each selecting circuit to make an independent selection in each to define the lower valued digits simultaneously.

When two signal elements are employed to effect a change in the fourth selecting circuit the first, second and third elements of the five-element code control the single switch nearest the apex in the first, second and third selecting

circuits to effect a selection in each by means of a single switch alone.

When one element only is employed to effect a selection in the fifth selecting circuit, the first, second, third and fourth signal elements of the five-element code control the single switch nearest the apex in each of the first, second, third and fourth selecting circuits to effect a selection in each by means of the single switch alone.

The cams, contacts and relay armatures in Figs. 1, 2, 3 and 4, are shown in the condition for the transmission and reception of code signals corresponding to the zero setting of the measuring instrument. The corresponding cam conditions are shown in vertical columns 500, 600 and 700 in Figs. 5, 6 and 7. For this condition a circuit may be traced from ground 129 through contact 161, contact 169, contact 170, contact 151 and the windings of relays 121 and 116 in series to battery operating the armatures of relays 121 and 116 to their lower positions. The circuits extending through the windings of relays 126, 122 and 117, 127, 123 and 118, 128, 124 and 119, 125 and 120 are open. Under this condition the armatures of these relays are restored to their upper positions by the effect of current flowing in their biasing windings.

Operation of first selecting circuit

When the armature of relay 116 engages contact 130, a circuit may be traced from negative battery, through contact 130, armature of relay 116, conductor 348 and the windings of relays 301 and 302 in series to positive battery. For this condition the armatures of relays 301 and 302 will be actuated to their lower positions. When the armatures of relays 117 to 120 are actuated to engage their upper contacts 133, 135, 137 and 139, positive battery is connected through their respective armatures, conductors 350, 352, 353 and 354 and the windings of relays 303 to 314 to positive battery. Under this condition, the armatures of relays 303 to 314 in the first selecting circuit will be operated to engage with their upper contacts due to the effect of current in their biasing windings. The armatures of all of the relays in selecting circuits 2 to 5 will be locked in the position indicated for reasons which will become apparent below.

Under these conditions, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 319, armature of relay 304, contact 321, armature of relay 302, contact 360 and conductor 410 to conducting ring 460 in lamp bank 450 in Fig. 4. Ring 460 is connected in parallel to the inner terminals of lamps 00, 13, 25, 38, 50, 63, 75 and 88. This results in a selection of eight lamps.

The lamps in lamp bank 450 are divided into eight groups. Eight lamps, one in each group have been selected. It is now necessary to select a particular one of the eight lamps. This is performed by connecting battery to the outer terminal of some particular one of the eight groups into which the lamps in indicator bank 450 are divided. With the armatures of the relays in the second selecting circuit, shown at the bottom of Fig. 2, arranged in the positions indicated, a circuit may be traced from positive battery, through the armature of relay 201, contact 225, contact 271 and conductor 400 which connects to the bank of lamps numbered 00 to 12. As a result of this, since battery is connected to the outer terminal of only one of the eight lamps

to the bottom terminal of which ground is connected, lamp 00 only will be lighted.

This indicates that the measuring instrument is set at the moment in the .00 hundredths of a unit position. The particular full unit position in which the measuring instrument is set is indicated in the following manner:

With the armatures of the relays in the third selecting circuit in the positions indicated, a circuit may be traced from ground through the armature of relay 202, contact 227, contact 284 and conductor 480 to the right-hand terminals of lamps 440 and 445 designated 0 units and 5 units. This results in a selection of one lamp in each of two groups of five. In order to complete the selection, a particular one of these two lamps must have battery connected to the left-hand terminal. This is performed in the following manner:

With the armatures of the relays in the fourth selecting circuit in the positions indicated, a circuit may be traced from positive battery through the armature of relay 204, contact 231, contact 298 and the winding of relay 423 to ground closing the contacts of relay 423. With the armatures of the relays in the fifth selecting circuit arranged as indicated, a circuit may be traced from battery through the armature of relay 208, contact 239, contact 218 and contact 430 to the left-hand terminal of lamps 440 to 444. Since battery is connected to the left-hand terminal of only one of the two lamps to the right-hand terminal of which ground is connected, lamp 0 only will light.

There now remains the explanation of the manner in which lamp 426 corresponding to the zero tens lamp is selected. This is performed by the fifth selecting circuit also. The path may be traced from battery through the armature of relay 208, contact 239, contact 218, contact 429 and the filament of lamp 426 to ground, lighting lamp 426. This is the lamp which indicates 0 in the tens position. The cooperation of the circuits, therefore, has resulted in a selection of lamps corresponding to the setting of the measuring instrument in position 00.00 units.

It will now be assumed that the position of the measuring instrument has been moved to 00.01 units. The permutation code set up on cams 101 to 105 is indicated in column 501 in Fig. 5. For this condition, cams 101 and 103 connect ground to conductors 180 and 182. Conductors 181, 183 and 184 are open. Relays 121 and 116 will operate. The operation of relay 116 will in turn operate relays 301 and 302 as heretofore described. With ground connected to conductor 182, the armatures of relays 127, 123 and 118 will be actuated to their lower positions. The closing of contact 134 will establish a circuit from negative battery through contact 134, armature of relay 118, conductor 352 and the windings of relays 304 and 305 in series to positive battery actuating the armatures of these relays to their lower positions. Positive battery will be connected to both ends of the circuits extending through the windings of each of the other relays in the first selecting circuits and their armatures will be in engagement with their upper contacts.

Attention is called to the fact that parallel branches extend from conductors 350, 352, 353 and 354 into other selecting circuits but in each instance the path which extends to ground connected to the armature of relay 121 is open. In the description to follow these parallel paths will be traced only when the circuits extending

through them are closed and the condition of the particular selecting circuit is changed in order to effect a new selection.

A circuit may now be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 313, armature of relay 304, contact 322, armature of relay 306, contact 325, armature of relay 309, contact 331 and conductor 411 to ring 461. Ring 461 connects in parallel to the inner terminals of lamps 01, 14, 26, 39, 51, 64, 76 and 89. There is no change in the condition of the other selecting mechanism. Battery remains connected to the outer terminals of the lamps in bank 00 to 12. Lamp 01, therefore, lights.

When the position of the measuring instrument changes to 00.02 units, the code set up on the cams is indicated by column 502 in Fig. 5. Cams 101, 103 and 105 close their respective contacts 152, 156 and 160 operating the armatures of relays 121, 116, 127, 123, 118, 125 and 120 to their lower positions. Negative battery is connected to the armatures of relays 116, 118 and 120. Relays 301, 302, 304 and 305 will be operated as heretofore explained. The closing of contact 138 will establish a circuit from negative battery through contact 138, armature of relay 120, and the windings of relays 309, 310, 311, 312, 313 and 314 in series to positive battery operating the armatures of these relays to their lower contacts. Other relay armatures will engage their upper contacts. Under these circumstances, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 319, armature of relay 304, contact 322, armature of relay 306, contact 325, armature of relay 309, contact 332 and conductor 412 to ring 462. This will effect a selection of lamp 02 in bank 450, the other selecting apparatus remaining unchanged.

When the measuring instrument is moved into position 00.03 units, the code set up on cams 101 to 105 will be as indicated in vertical column 503 in Fig. 5. Cams 101, 103, 104 and 105 will close their respective contacts 152, 156, 158 and 160. The armatures of relays 121, 116, 127, 123, 118, 128, 124, 119, 125 and 120 will engage their lower contacts. Relays 301, 302, 304, 305 and 309 to 314 will remain as heretofore described. The operation of the armature of relay 119 to close contact 136 establishes a circuit from negative battery through contact 136 and the windings of relays 306, 307 and 308 in series to positive battery operating the armatures of these relays to their lower positions. The armatures of the other relays will engage their upper contacts. For this condition, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 319, armature of relay 304, contact 322, armature of relay 306, contact 326, armature of relay 310 and contact 334 to conductor 413 which connects to ring 463. Ring 463 is connected in parallel to the inner terminals of lamp 03 and a corresponding lamp in each of the other seven groups. However, since the condition of the other selecting apparatus remains unchanged, battery will remain connected to the outer terminal of the lamps in the first bank only so that lamp 03 alone will light in indicator bank 450.

Changing the measuring instrument to position 00.04 units, as indicated in vertical column 504 in Fig. 5, will operate the armature of relays 309 to 314 to their upper contacts while the other relays in the first selecting circuit remain in the condition indicated for the .03 selection. Under this condition, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 319, armature of relay 304, contact 322, armature of relay 306, contact 326, armature of relay 310, contact 333 and conductor 414 to ring 464. Ring 464 is connected to the inner terminal of lamp 04 and to a corresponding terminal in each of the other seven groups of lamps. Lamp 04 will light, the others will remain unlighted.

When the position of the measuring instrument is changed to indicate 00.05 units, the armatures of relays 301 to 308 will all be actuated to their lower positions. The armatures of relays 309 to 314 will be in their upper positions. For this condition, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 324, armature of relay 308, contact 330, armature of relay 314, contact 341 and conductor 415 to ring 465. Ring 465 connects in parallel to the inner terminal of lamp 05 and to the inner terminal of a corresponding lamp in each of the other seven groups of lamps in lamp bank 450. Lamp 05 will be lighted since the other selecting apparatus remains unchanged. The other lamps will remain unlighted.

The permutation code set up on the cams when the measuring instrument is moved into the position for 00.06 units is indicated in vertical column 506. For this condition, the armatures of relays 301 to 314 are all actuated to their lower positions. Under this condition, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 324, armature of relay 308, contact 330, armature of relay 314, contact 342 and a conductor 416 to ring 466. Ring 466 connects to lamp 06 and to a corresponding lamp in lamp groups 25 to 37, 50 to 62 and 75 to 87 only. There is no corresponding lamp in lamp banks 13 to 24, 38 to 49, 63 to 74, and 88 to 99. Since battery remains connected to the outer terminal of lamps 00 to 12, lamp 06 only of lamp bank 450 will light.

When the measuring instrument is moved into the position for 00.07 units, as indicated in vertical column 507 in Fig. 5, negative battery will be connected to conductors 348, 350 and 352 operating the armatures of relays 301 to 305 to their lower positions. For this condition, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 324, armature of relay 308, contact 329, armature of relay 313, contact 339 and conductor 417 to ring 467. Ring 467 connects to the inner terminals of lamp 07 and a corresponding lamp in each of the other seven groups of lamps in lamp bank 450. Lamp 07 only lights as battery is connected to the outer terminals of group 00 to 12 only.

When the measuring instrument moves to the position for 00.08 units, negative battery is connected to conductors 348, 350, 352 and 354. The armatures of relays 301 to 305 and 309 to 314 will be operated to their lower position. A circuit may then be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 324, armature of relay 308, contact 329, armature of relay 313, contact 340 and conductor 418 to ring 468. Ring 468 connects to the inner terminal of lamp 08 in group 00 to 12 and to

the inner terminal of a corresponding lamp in each of the other seven groups. Lamp 08 lights, the others remain unlighted.

When the measuring instrument is moved into position for 00.09 units, negative battery is connected to conductors 348, 350 and 354. Conductors 352 and 353 are connected to positive battery. Under this condition the armatures of relays 301, 302, 303 and 309 to 314 are operated to their lower positions. A circuit may then be traced from ground, through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 323, armature of relay 307, contact 327, armature of relay 311, contact 336 and conductor 419 to ring 469. Ring 469 is connected to the inner terminal of lamp 09 in group 00 to 12 and to the inner terminal of a corresponding lamp in each of the other seven lamp groups. Lamp 09 will light and the other lamps will remain unlighted.

When the measuring instrument is moved into the position for 00.10 units, negative battery is connected to conductors 348, 350, 353 and 354. The armatures of relays 301, 302, 303 and 306 to 314 will be operated to their lower positions. Under this condition, a circuit may be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 323, armature of relay 307, contact 328, armature of relay 312, contact 338 and conductor 420 to ring 470. Ring 470 connects to the inner terminal of lamp 10 in lamp group 00 to 12 and to an inner terminal of a corresponding lamp in each of the other seven lamp groups. Lamp 10 will light and the other lamps will remain unlighted.

When the measuring instrument is moved into the position for 00.11 units, negative battery is connected to conductors 348, 350 and 353. Conductors 352 and 354 are connected to positive battery. Under this condition, the armatures of relays 301, 302, 303, 306, 307 and 308 are operated to their lower positions. A circuit may then be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 323, armature of relay 307, contact 328, armature of relay 312, contact 337 and conductor 421 which connects to ring 471. Ring 471 is connected to the inner terminal of lamp 11 in lamp group 00 to 12 and to the inner terminal of a corresponding lamp in each of the other seven lamp groups. Lamp 11 only lights.

When the measuring instrument is moved into the position for 00.12 units, negative battery is connected to conductors 348 and 350, and positive battery is connected to conductors 352, 353 and 354. The armatures of relays 301, 302 and 303 will operate to their lower positions. A circuit may then be traced from ground through the armature of relay 301, contact 317, armature of relay 303, contact 320, armature of relay 305, contact 323, armature of relay 307, contact 327, armature of relay 311, contact 335 and conductor 422 which connects to ring 472. Ring 472 connects to the inner terminal of lamp 12 in lamp group 00 to 12 and to the inner terminal of a corresponding lamp in each of the other seven groups of lamps. Lamp 12 only lights.

Operation of second selecting circuit

When the measuring instrument moves into the position for 00.13 units, cams 101 to 106 will each actuate its corresponding follower to close its left-hand contact. Under this condition, conductors 180 to 184 respectively, are extended through contacts 151, 153, 155, 157 and 159 respectively. Since contact 161 will be closed, ground 129 will be connected through contact 161 to conductor 195. During the interval while the cams 101 to 106 were moving through thirteen-twenty-fifths of a revolution, cams 107 to 111 will have each rotated into the next code position. The movement of the cams of the middle row sets up a cam and contact pattern in accordance with vertical row 601 in Fig. 6. Contacts 162 and 164 are closed. Contacts 165, 166, 167 and 168 and 169 are all open. The opening of contact 169 disconnects the ground supply to the top row of cams. A circuit may be traced from ground 129 through contact 161 and conductor 195 to parallel branches. One branch extends through contact 164, 155, conductor 182 and the windings of relays 127, 123 and 118 in series to battery. Another branch extends through contacts 162, 153, conductor 181 and the windings of relays 126, 122 and 117 in series to battery. The armatures of these relays will be actuated to their lower positions. The armatures of all other relays in Fig. 1 will be operated to their upper positions due to the effect of current in their biasing windings.

It is pointed out that relays 117 to 120 transmit polar signals to control the armature of the polar relays in the second, third, fourth and fifth selecting circuits. The polar signals are impressed on the left-hand windings of relays in these circuits simultaneously. A single return path to ground connected to the armature of relay 121 is provided for each selecting circuit. The return path for the different selecting circuits extends through the armature of relays 121 to 125. This path is open due to the positions of the relay armatures except when the particular selecting circuit is intended to respond. After selecting paths are established through the second, third, fourth and fifth selecting circuits, they are locked locally through the armature and contact of each relay in the chain in each selecting path. The selecting paths through each of selecting circuits 2 to 5 are maintained, once they are established, by their respective local locking circuits until the path to ground on the armature of relay 121 is provided at the proper time. Then the relays in the selecting circuits for which ground has been provided respond to the polar signals of the changed code to set up new selections.

When the armature of relay 117 operates to engage contact 132, a circuit may be traced from negative battery through the armature of relay 117 to parallel branches. The only effective branch for this condition extends through the left-hand winding of relay 201, conductor 355, contact 141, armature of relay 122 and contact 140, which is now closed, through the armature of relay 121 to ground. The armature of relay 201 is operated to its lower position to engage contact 226.

The operation of the armature of relay 118 to engage contact 134 establishes a circuit which may be traced from negative battery through contact 134, armature of relay 118 and conductor 352 to parallel branches. The only effective branch for this condition extends through the left-hand winding of relay 203 over a circuit which has been traced through conductor 355 to ground connected to the armature of relay 121. The armature of relay 203 is operated to its lower position closing contact 230.

The armature of relay 119 engages contact 137. A circuit may be traced from positive battery through contact 137, armature of relay 119 and conductor 353 to parallel branches. The branch through the second selecting circuit which is the only effective branch for this condition extends in series through the left-hand windings of relays 206 and 207 to the common ground by way of conductor 355. Positive battery operates the armatures of relays 206 and 207 to their upper positions.

The armature of relay 120 engages its upper contact. A circuit may be traced from positive battery through contact 139 and the armature of relay 120 to parallel branches. The only effective branch extends through the winding of relays 212 to 215 in series and through conductor 355 to the common ground connected to the armature of relay 121. Positive battery operates the armatures of relays 212 to 215 to their respective upper contacts.

Attention is called to the fact that whereas negative battery has heretofore been connected at all times to conductor 348 maintaining the armatures of relays 301 and 302 in their lower positions to supply ground through the various other relays in the first selecting circuit, the armatures of relays 301 and 302 are now operated to their upper positions. Under this condition a circuit may be traced from ground through the armature of relay 301, contact 318 and conductor 410 to ring 460. Ring 460 as has been explained connects to the inner terminal of the lowest numbered lamp in each of the eight lamp groups in lamp bank 450.

Whenever conductors 180 to 184 are cut through to any of the higher valued cams a selection of the lowest numbered lamp in each of the eight lamp groups of lamp bank 450 is effected by the operation of the armature of relay 301 to engage contact 318 so that ground is connected to conductor 410 and to ring 460 directly without passing through the armatures and contacts of any other relays in the first selecting circuit. From this it should be apparent that whether or not the settings of the relays other than relay 301 are changed at such times, the changes do not establish any selections and they are ineffective as the selection is effected in each case solely by the operation of the armature of relay 301 to its upper position. It is emphasized, and reference to the top horizontal lines in Figs. 6 and 7 shows, that except in the selection for 00.00 the armature of relay 301 is always actuated to its upper position when the transmitting channels are connected to the middle and top row of cams. The lowest numbered lamp in each of the eight groups is selected by the first selecting circuit when the middle row of cams is in control and the 00 lamp is always selected by the first selecting circuit in cooperation with the second selecting circuit when the top row of cams is in control. The reason for this will become more apparent from the description hereinafter.

Formerly battery was supplied through the armature of relay 201 to lamp group 00 to 12 to light lamp 00. The selection made by the second selecting circuit has now for the first time been changed. The new selection may be traced from battery through the armature of relay 201, contact 226, armature of relay 203, contact 230, armature of relay 207, contact 237, armature of relay 214, contact 251, contact 269 and conductor 401 to the outer terminals of lamp group 13 to 24.

Attention is called to the fact that every time a selection is made in the second, third, fourth or fifth selecting circuits, the armature of each relay in the selecting chain is locked in position to maintain the selection.

Certain of the locking paths will be traced by way of example. In the case of the selecting path which supplied battery to the outer terminal of lamps 00 to 12 in lamp bank 450, the circuit extended through the armature of relay 201 and contact 225 only in the second selecting circuit. The armature of relay 201 was locked in this position by the circuit extending from positive battery through contact 225 and the middle winding of relay 201 to ground. For the second selection of lamp groups 13 to 24 in lamp bank 450, the circuits for locking the armatures of relays 201 and 203 in their lower positions and the armatures of relays 207 and 214 in their upper positions extends from battery connected to the armature of relay 201 along the chain, through the armature and contact of each relay involved in the selection through a locking winding on each relay to ground.

The selecting path for the 13 to 24 group of lamps in lamp bank 450 may be traced from battery through the armature of relay 201, contact 226, armature of relay 203, contact 230, armature of relay 207, contact 237, armature of relay 214, contact 251, contact 269 and conductor 401 to lamp group 13 to 24. Lamp 13 is lighted since the first selecting circuit, as has been shown, simultaneously selects the first lamp in each group.

Lamp 426 corresponding to 0 in the tens group and lamp 440 corresponding to 0 in the units group remain unaffected as the third, fourth and fifth selecting circuits have not been altered. The lighted lamps correspond to a setting of 00.13 units.

When the position of the measuring instrument is changed to the 00.14 setting cams 101 to 106 are rotated into their next succeeding position. In this position conductors 180 to 184 are no longer cut through to the higher valued cams and cams 107 to 110 no longer control the settings of the relays in the second selecting circuit. This explains why the relays in the second selecting circuit have been locked as their settings must be maintained during the interval while the measuring instrument is in the region between .13 and .24 units.

Attention is called to the fact that the relays in the first selecting circuit are not locked. During the interval while conductors 180 to 184 were cut through to the higher valued cams, the first selecting circuit is arranged so that it selects the inner terminal of the lowest numbered lamp in each group. Therefore, while conductors 180 to 184 are cut through to the next higher valued cams, two selections are being made rather than one and this is accomplished by effecting a selection by the first selecting circuit by means of one signal element alone. The various codes assigned have been arranged so that, whenever conductors 180 to 184 are cut through to the higher valued cams, except for the condition for 00.00 units, relay 301 is always released.

It will be assumed that the position of the measuring instrument continues to change as the measured quantity is increased. As the quantity is increased in the range from 00.13 units to 00.24 units each of the one-hundredth unit codes used

for the setting from .01 unit to .12 unit will be repeated except the code for .06 unit. This may be seen from a comparison of vertical columns 501 to 512 in Fig. 5 with vertical columns 514 to 524. Each of these transmitted codes results in the connection of ground to the inner terminal of a different one of lamps 13 to 24, inclusive, in lamp bank 450.

When the measuring instrument is in the position for 00.25 units, conductors 180 to 184 will again be cut through to the middle group of cams. Reference to column 602 in Fig. 6 indicates that for this condition, cams 107, 108 and 110 close contacts 162, 164 and 168, respectively. Contact 166 associated with cam 109 is open. The armatures of relays 117, 118 and 120 are operated to engage their lower contacts. The armature of relay 119 is operated to engage its upper contact. Negative battery is connected to conductors 350, 352 and 354. Positive battery is connected to conductor 353. It is pointed out that the effect of positive or negative current in the left-hand or operating windings of the relays in selecting circuits 2 to 5 is dominant over the effect of the holding current in these relays. The armatures of relays 201, 203 and 212 to 215 are operated to their lower positions. The armatures of relays 206 and 207 are operated to their upper positions.

The selecting circuit for lamp group 25 to 37 in lamp bank 450 may now be traced from battery through the armature of relay 201, contact 226, armature of relay 203, contact 230, armature of relay 207, contact 237, armature of relay 214, contact 252, contact 264 and conductor 402 to the outer terminals of lamps 25 to 37.

As the measured quantity continues to increase cams 101, 106 will continue to rotate. When the measuring instrument is in a setting corresponding to 00.26 units, conductors 180 to 184 will be disconnected from their respective cams in the middle row. While the second selecting circuit remains in the condition of supplying battery over conductor 402 to the outer terminal of lamps 25 to 37 of lamp bank 450, cams 101 to 105 will resume control. Permutation code signals will be transmitted to effect the selection of lamps 26 to 37 in lamp bank 450 in the same manner as described for the corresponding lamps in lamp group 00 to 12. Then once more raised surfaces on the peripheries of cams 101 to 106, will make the middle row of cams effective for the next selection. Reference to vertical column 603 in Fig. 6 shows that for this condition cams 107 to 110 close their respective right-hand contacts and operate their respective relays in Fig. 1. Negative battery is therefore connected to conductors 350, 352, 353 and 354. The armatures of relays 201, 203, 206, 207 and 212 to 215 will be actuated to engage their lower contacts. The selecting circuit extends from battery through the armature of relay 201, contact 226, armature of relay 203, contact 230, armature of relay 207, contact 238, armature of relay 215, contact 254, contact 262 and conductor 403 to the outer terminals of lamps 38 to 49. The armature of relay 301 is simultaneously operated to its upper position to engage contact 318 which will again effect the selection of ring 460 in a manner heretofore described so that lamp 38 of lamp group 38 to 49 will be lighted.

When the position of the measuring instrument is moved to 00.39 units, cams 101 to 105 again resume control. The inner terminals of lamps 39 to 49 will be selected in a manner corresponding to that heretofore described while battery remains connected from the second selecting circuit to lamp group 38 to 49 in lamp bank 450.

When the position of the measuring instrument has been changed to correspond to a setting of 00.50 degrees, the relay settings of the second selecting circuit will be changed to correspond to the code indicated in vertical column 604 of Fig. 6.

Reference to vertical column 604 in Fig. 6 indicates that cams 107, 108 and 109 close their right-hand contacts operating the armature of the corresponding relays to engage their lower contacts. The selections by the second selecting circuit involve the operation of the armatures of relays 201, 203, 206 and 207 to their lower positions and the operation of the armature of relays 212 to 215 to their upper positions. Under this condition, a circuit may be traced from battery through the armature of relay 201, contact 226, armature of relay 203, contact 230, armature of relay 207, contact 238, armature of relay 215, contact 253, contact 272 and conductor 404 which connects to the outer terminals of lamps 50 to 62. Lamps in the 50 to 62 group will therefore be lighted as the measuring instrument operates in this zone.

When the measuring instrument moves to a position corresponding to 00.63 units, reference to vertical column 605 in Fig. 6 discloses that cams 107 and 109 close their right-hand contacts actuating the armature of the corresponding relays in Fig. 1 to engage their lower contacts. The armatures of relays 201, 206 and 207 in the second selecting circuit will be actuated to engage their respective lower contacts. The armatures of all other relays will engage their upper contacts. For this condition, a circuit may be traced from positive battery through the armature of relay 201, contact 226, armature of relay 203, contact 229, armature of relay 206, contact 236, armature of relay 213, contact 249, contact 277 and conductor 405 to the outer terminals of the lamps 63 to 74. This selection will be maintained while the measuring instrument measures quantities in the range 00.63 to 00.74 units. Meanwhile ground will be connected from the first selecting circuit to the inner terminals of the lamps in lamp group 63 to 74 in the manner described.

Reference to vertical column 606 in Fig. 6, indicates that for this condition, cams 107, 109 and 110 will close their associated right-hand contacts operating the armatures of the corresponding relays in Fig. 1 to their lower positions. The armatures of relays 201, 206, 207, 212, 213, 214 and 215 will be actuated in turn to their lower positions, while the armature of relay 203 is actuated to its upper position. For this condition, a circuit may be traced from positive battery through the armature of relay 201, contact 226, armature of relay 203, contact 229, armature of relay 206, contact 236, armature of relay 213, contact 250, contact 274 and conductor 406 to the outer terminals of lamps 75 to 87. During the interval while the measuring instrument is changing through the region 00.75 units to 00.87 units, ground will be connected by the first selecting circuit to the inner terminals of these lamps to light lamps corresponding to the setting of the instrument.

When the measuring instrument is moved to position 00.88 units, reference to vertical column 607 in Fig. 6 indicates that cams 107 and 110 close their respective right-hand contacts operating the armatures of the corresponding relays in Fig. 1 to their lower positions. The armatures of relays

201, and 212 to 215 will be actuated in turn to their lower positions. The armatures of relays 203, 206 and 207 will be actuated to their upper positions. Under this condition, a circuit may be traced from positive battery through the armature of relay 201, contact 226, armature of relay 203, contact 229, armature of relay 206, contact 235, armature of relay 212, contact 248, contact 279 and conductor 407 to the outer terminals of lamps 88 to 99 in lamp bank 450. While this selection is maintained by the locking circuit, ground will be connected to the inner terminals of lamps 88 to 99 to light lamps corresponding to the instrument setting.

Up to the present it hast been assumed that the measuring instrument has been changing through the region from 00.00 units to 00.99 units. The settings of the armatures in the third, fourth and fifth selecting circuits have been maintained unchanged during this interval. Lamps 426 and 440 have been lighted during this interval to complete the indication. The position of the measuring instrument is now to be changed so that it moves into the 01.00 unit zone. It is necessary, therefore, to extinguish lamp 440 and light lamp 441 to indicate this change. The manner in which this is effected will now be explained.

Operation of third, fourth and fifth selecting circuits

Each time that the measuring instrument is in position such that the two right-hand digits of the measured quantity correspond to zero, the position of cams 101 to 106 and 107 to 111 will be such that conductors 181 to 184 are further extended to the top row of cams to transmit the codes for the higher valued digits as well as for zero in the two right-hand positions of the number simultaneously.

A circuit may be traced from ground 129 through contact 161 and contact 169, to contacts 170 to 173 in parallel. Reference to column 701 of Fig. 7 indicates that for the 01.00 full unit setting, the contacts associated with cam 113 and 114 are closed and that contacts 170 and 173 associated with cams 112 and 115, respectively, are open. The circuit, therefore, extends through contact 171, contact 163, contact 155 and the windings of relays 127, 123 and 118 to positive battery, operating the armatures of relays 127, 123 and 118 to their lower positions. A parallel circuit extends through contact 172, contact 165, contact 157 and the windings of relays 128, 124 and 119 in series to positive battery, operating the armatures of relays 128, 124 and 119 to their lower positions. The armatures of relays 125 and 120 will be in their upper positions.

Attention is called to the two top horizontal lines in Fig. 7 which indicate that except for the 00.00 unit selection, both cams 112 and 107 maintain their associated contacts open at all times while the top row of cams is functioning to transmit codes defining the higher valued digits. Relays 116 and 117 therefore will always transmit positive battery to the first and second selecting circuits at such times so that the armatures of relays 301 and 302 in the first selecting circuit and of relay 201 in the second selecting circuit will engage their upper contacts, at such times and will always make a selection of the 00.00 lamp in lamp bank 450. In other words, except in the case of the 00.00 unit selection, the armatures of relays 301 and 302 are always operated to their upper positions whenever the transmission conductors connecting the stations are cut through

to the middle row of cams. And whenever the transmission conductors 180 to 184 are cut through to the top row of cams, not only is the armature of relay 301 in its upper position so as to supply ground to the inner terminal of the first lamp in each one of the eight lamp groups in lamp bank 450, but the armature of relay 201 is also on each such occasion operated to engage its upper contact 225 so as to connect battery to the outer terminals of lamps 00 to 12. As a result of this, the .00 lamp in lamp bank 450 is always selected whenever transmission conductors 180 to 184 are cut through the two lower valued groups of cams to the top row of cams which control the transmission of codes for full units. From this it should be apparent that now three selections are made when a full unit selection is made.

Before proceeding to describe the manner in which lamp 441 corresponding to full unit 1 is selected, the manner in which the relays which are locked in position for each selection in the second selecting circuit are unlocked will first be explained. It was heretofore explained that as the armatures of the various relays in the second selecting circuit involved in making any particular selection were operated to one or the other of their respective contacts, they were locked in that position, while the measuring instrument remained in the corresponding zone. Each of the relays in the second selecting circuit responds to polar signals transmitted from relays 117 to 120. The path in each instance extends from positive or negative battery connected to the armatures of relays 117 to 120 through the left-hand windings of the relays in the second selecting circuit, through common conductor 355 to ground connected to the armature of relay 121. The effect of current flowing in this path, whether it be from positive or negative battery, preponderates over the effect of the locking current so that the relays respond to the polar signals for each new selection.

When the transmitting conductors are connected through to the top row or full unit cams, the armatures of relays 122 and 117 are always actuated so as to engage their respective upper contacts due to the effect of current in their biasing windings. Under this condition, a circuit may be traced from positive battery, through contact 133, armature of relay 117, conductor 350, left-hand winding of relay 201, and conductor 355. Since the armature of relay 122 no longer engages contact 141, an alternative path has been established through contact 148, armature of relay 126, and contact 143, the armature of relay 123 being operated to its lower position, through the armature of relay 123, contact 142, armature of relay 122, contact 140 and the armature of relay 121 to ground. Reference to the middle horizontal line in Fig. 7 discloses that except for the 0, 5, 10, 15, 20 and 25 unit settings of the measuring instrument, cam 113 is in condition so that contact 171 is always closed for each of the full unit selections. Contacts 163 and 155 are also always closed so that the armatures of relays 127, 123 and 118 are always in their lower positions for every full unit selection except in the selections of full units which are multiples of five. As a result of this, the armature of relay 201 will always be actuated to engage and lock with its upper contact 225 for everyone of the full unit selections which is not a multiple of five over the path which has been traced to ground connected to the armature of relay 121 through contact 148. For the full unit selections which are multiples

of five, the armature of relay 201 will also be actuated to engage its upper contact in a manner to be understood from the following, so that when the measuring instrument is moved into any full unit position, the armature of relay 201 will always be actuated to engage its contact 225 and make a selection, as has been shown, of the outer terminals of lamps .00 to .12 in lamp bank 450. At the same time, the first selecting circuit cooperates to select lamp .00.

Reference to vertical column 701 in Fig. 7 discloses that in selecting the lamp corresponding to one full unit, cams 113 and 114 close their respective contacts. The armatures of relays 118 and 119 are actuated to their lower positions. The armature of relay 120 is actuated to its upper position. In the case of relay 118, a circuit is established from negative battery through contact 134, armature of relay 118, left-hand winding of relay 202, conductor 356, contact 143, armature of relay 123, contact 142, armature of relay 122, contact 140 and armature of relay 121 to ground, operating the armature of relay 202 to its lower position. With the armature of relay 119 operated to engage its lower contact, a circuit may be traced from negative battery, through contact 136, armature of relay 119, conductor 353, left-hand winding of relay 205 to conductor 356 which extends as has been shown to ground connected to the armature of relay 121. Since the armature of relay 120 engages its upper contact 139, a circuit may be traced fom positive battery, through contact 139, armature of relay 120, conductor 354 and the left-hand windings of relays 210 and 211 in series to conductor 356 which extends to ground connected to the armature of relay 121. The armatures of relays 210 and 211 are actuated to engage their upper contacts. A circuit may now be traced from ground through the armature of relay 202, contact 228, armature of relay 205, contact 234, armature of relay 211, contact 245, contact 282 and conductor 481 to the right-hand terminals of lamps 441 and 446 corresponding to full unit indications of 1 and 6.

The relays in the fourth and fifth selecting circuits have assumed the positions shown as a result of operation in a previous cycle of operation which may be understood from the description hereinafter. A circuit may be traced from battery through the armature of relay 204, contact 231, contact 298 and the winding of relay 423 in Fig. 4 to ground, so that the contacts associated with relay 423 are all closed at this time. The armatures of relays 423 will remain in the operated positions as the winding of relay 423 is maintained energized while the selecting path through the fourth selecting circuit is maintained by its locking circuit. A circuit may also be traced from battery through the armature of relay 208, contact 239, contact 218 and contact 430 to the left-hand terminal of units lamps 440 to 444. Lamp 441 which corresponds to full unit 1 will light. A circuit may also be traced from positive battery through the armature of relay 208, contact 239, contact 218, contact 429 and the filament of lamp 426 to ground so that the zero tens lamp is lighted. The lighted lamps 426, 441 and .00 indicate a setting of the measuring instrument corresponding to 01.00 units.

When the measuring instrument is moved into the position corresponding to the setting for 01.01 units, cams 101 to 105 will resume control and the cycle of operations may be repeated while the measuring instrument moves through the range from 01.01 to 01.99 units. The first and second selecting circuits will cooperate to select each one of the lamps from .01 to .99 in lamp bank 450 as the measuring instrument sweeps through the positions from 01.01 to 01.99 units. Thereupon the transmitting conductors will be again cut through to the full unit cams. On this occasion, as may be seen from reference to vertical column 702 in Fig. 7, cams 113, 114 and 115 close contacts 171, 172 and 173 respectively. The armatures of relays 127, 123, 118, 128, 124, 119, 125 and 120 will all be actuated to their lower positions. The armatures of relays 202 and 205 will again be actuated to their lower positions. The closing of contact 138 establishes a circuit from negative battery through contact 138, armature of relay 120, conductor 354, left-hand windings of relays 210 and 211 to conductor 356 which extends to ground connected to the armature of relay 121. The armatures of relays 210 and 211 will be operated to their lower postions. A circuit may then be traced from ground through the armature of relay 202, contact 228, armature of relay 205, contact 234, armature of relay 211, contact 246, contact 280 and conductor 482 to the right-hand terminals of lamps 442 and 447 corresponding to full units 7 and 2. The condition of the fourth and fifth selecting circuits remains unchanged as they cannot respond to the polar signals transmitted by relays 119 and 120 since the path to ground connected to the armature of relay 121 is open in each instance. Battery will, therefore, remain connected to the left-hand terminal of lamps 440 to 444 corresponding to full units 0 to 4 and lamp 2 will light.

When the transmitting conductors are again cut through to the full unit cams, when the measuring instrument is in the position corresponding to 03.00 units, as indicated in column 703 of Fig. 7, the armatures in Fig. 1 controlled by cams 113 and 115 will be in their lower positions. The armatures of other relays in Fig. 1 will be in their upper positions. For this condition, the armature of relays 202, 210 and 211 will be operated to their lower positions and the armature of relay 205 will be operated to its upper position. A circuit may then be traced from ground to the armature of relay 202, contact 228, armature of relay 205, contact 233, armature of relay 210, contact 244, contact 289 and conductor 483 to the right-hand terminals of lamps 433 and 448 corresponding to full units 3 and 8. Battery will be connected to the right-hand terminal of lamp 443 and lamp 443 corresponding to full unit 3 will light.

When the measuring instrument has moved into position corresponding to 04.00 units as indicated in vertical column 704 in Fig. 7, contact 171 associated with cam 113 will close to operate the armatures of relays 127, 123 and 118 to their respective lower positions. The armatures of all other relays in Fig. 1 will be in their upper position. For this condition, the armature of relay 202 is actuated to its lower position. The armatures of other relays in the third selecting circuit will be actuated to their upper positions. A circuit may be traced from ground through the armature of relay 202, contact 228, armature of relay 205, contact 233, armature of relay 210, contact 243, contact 291 and conductor 484 to the right-hand terminals of lamps 444 and 449 corresponding to full units 4 and 9. Since battery remains connected to the left-hand terminal of lamps 0 to 4, lamp 4 will light.

For the 05.00 degrees position of the measuring

instrument, as indicated in vertical column 705 in Fig. 7, cams 114 and 115 close contacts 172 and 173. The armatures of relays 128, 124, 119, 125 and 120 will be actuated to their lower positions. The armatures of all other relays in Fig. 1 will be in their upper positions.

Attention is particularly called to the fact that in this position of the measuring instrument, as in each full unit position which is a multiple of five, the armatures of relays 127, 123 and 118 are in their upper positions. For this condition the armature of relay 202 will be actuated to its upper position. The circuit may be traced from positive battery through contact 135, armature of relay 118, conductor 352, left-hand winding of relay 202, conductor 356, contact 149, armature of relay 127, contact 145, armature of relay 124, contact 144, armature of relay 123, contact 142, armature of relay 122, contact 140 and the armature of relay 121 to ground. A circuit may then be traced from ground through the armature of relay 202, contact 227, contact 284, and conductor 480 to the right-hand terminals of lamps 440 and 445 corresponding to full units 0 and 5. The operation of the armature of relay 119 to its lower position establishes a circuit from negative battery through contact 136, armature of relay 119, conductor 353, left-hand winding of relay 204, conductor 357, contact 145, armature of relay 124, contact 144, armature of relay 123, contact 142, armature of relay 122, contact 140 and the armature of relay 121 to ground, operating the armature of relay 204 to its lower position. The closing of contact 138 establishes a circuit from negative battery through contact 138, armature of relay 120, conductor 354, left-hand winding of relay 209 and conductor 357 which extends to ground connected to the armature of relay 121. The armature of relay 209 is operated to its lower position. A circuit may then be traced from positive battery through the armature of relay 204, contact 232, armature of relay 209, contact 242, contact 292, and the winding of relay 424 to ground, operating relay 424. A circuit may now be traced from positive battery through the armature of relay 208, contact 239, contact 218 and contact 490 to the left-hand terminals of lamps 445 to 449 corresponding to full units 5 to 9. Lamp 445 corresponding to full unit 5 will, therefore, light, Relay 424 is maintained operated due to the locking of the armatures of relays 204 and 209 in their lower positions.

For codes corresponding to 06.00, 07.00, 08.00 and 09.00 units as may be seen from reference to vertical columns 706, 707, 708 and 709 in Fig. 7, cam 113 closes its contact and consequently the armature of relay 202 is operated to its lower position in each instance. This breaks the original path to ground over which the armatures of relays 204 and 209 were operated to their lower positions. But since as has been explained relays 204 and 209 are locked over local paths within the fourth selecting circuit itself, the armatures of relays 204 and 209 remain locked in their lower positions. This in turn maintains relay 424 operated to maintain battery connected to the left-hand terminals of full units lamps 5 to 9 while selections of these lamps are made by the third selecting circuit which connects ground to each one of their right-hand terminals as its proper code is received from relays 118 to 120.

Comparison of vertical columns 706 to 709 with vertical columns 701 to 704 in Fig. 7 indicates that the codes for settings 6 units to 9 units are the same as for 1 unit to 4 units, respectively.

Each one of the corresponding selections by selecting circuit 3 has been shown to select units lamps 1 and 6, 2 and 7, 3 and 8, and 4 and 9 in pairs. With battery from the fifth selecting circuit now remaining connected to the left-hand terminals of units lamps 5 to 9 in parallel, units lamps 6 to 9 will be selected in response to the codes shown in vertical columns 706 to 709 in Fig. 7.

The code for the setting of the measuring instrument at ten full units is shown in vertical column 710.

Once again for reasons explained the armatures of relays 116 to 118 are all in their upper positions. The fourth selecting circuit is free to respond. Cam 114 alone closes its contact. The armature of relay 204 in the fourth selecting circuit is again operated to its lower position. The armatures of other relays in the fourth selecting circuit remain in their upper positions.

A circuit may now be traced from battery through the armature of relay 204, contact 232, armature of relay 209, contact 241, contact 294, and the winding of relay 425 to ground, closing the contacts of relay 425.

The fifth selecting circuit remains unchanged. A circuit may therefore be traced from battery through the armature of relay 208, contact 239 and contact 218 to parallel branches. One branch extends through contact 436 and the filament of lamp 427 to ground lighting lamp 427, which is the lamp corresponding to settings in the range from 10.00 units to 19.99 units. The other parallel branch extends through contact 437 to the left-hand terminal of lamps 440 to 444 which are full units lamps 0 to 4. Simultaneously the right-hand terminals of lamp 0 will be selected by the third selecting circuit while the first and second cooperate to select the .00 lamp in lamp bank 450.

When the position of the measuring instrument advances the fourth and fifth selecting circuits remain locked to maintain the selection of lamp 427 until, as indicated from reference to vertical column 715 in Fig. 7, the instrument setting reaches the 15.00 unit position.

During this interval the first, second and third selecting circuits respond to the permutation code signals from the cams in a manner which should be understood from the foregoing to control their respective full units lamps and the lamps in lamp bank 450.

When the setting of the measuring instrument reaches 15.00 units, reference to vertical column 715 of Fig. 7 and the foregoing description indicates that cam 115 alone closes its contact. Consequently, the armature of relay 208 will be actuated to its lower position over a circuit from negative battery through contact 138, armature of relay 120, left-hand winding of relay 208, contact 147, armature of relay 125, contact 146, armature of relay 124, contact 144, armature of relay 123, contact 142, armature of relay 122, contact 140 and armature of relay 121 to ground. Positive battery connected to the armatures of each of relays 116, 117, 118 and 119 will operate the armatures of relays 301, 201, 202 and 204 to engage their upper contacts.

The cooperation of the first and second selecting circuits will result in the usual selection of the .00 lamp in lamp bank 450. The third selecting circuit will connect battery to the right-hand terminal of full units lamps 0 and 5. The fourth selecting circuit will reoperate relay 423. Under this condition a circuit may be traced from bat-

tery through the armature of relay 208, contact 240 and contact 216 to parallel circuits. One branch extends through contact 431 and through the filament of lamp 427 to ground to maintain the middle tens lamp lighted. The second branch extends through contact 432 to the left-hand terminal of lamps 445 to 449 corresponding to full units 5 to 9. Lamp 445 or unit lamp 5 will light. The lighting of this combination of lamps provides the 15.00 unit indication.

Reference to Fig. 7 discloses that the codes for each of the four different full unit settings between multiples of five are the same. For instance, the codes for 1, 2, 3 and 4 units are the same as for 6, 7, 8 and 9 units, etc. The third selecting circuit functions in the same manner for each group of four. For each code received by the third selecting circuit ground is connected to the right-hand terminal of a different lamp in each of the two groups of units lamps.

For the 20.00 unit setting, reference to vertical column 720 indicates that cams 114 and 115 close their contacts. The armatures of relays 119 and 120 will be actuated to their lower positions. When the armature of relay 119 engages with its bottom contact a circuit is established from negative battery through contact 136, armature of relay 119, conductor 353, left-hand winding of relay 204, conductor 357, contact 145 and through the armatures and upper contacts of each of the other relays in the chain circuit which extends to ground connected to the armature of relay 121. The armature of relay 204 will be actuated to close its contact 232. When the armature of relay 120 engages with its contact 138 a circuit is closed which extends from negative battery through contact 138, armature of relay 120, left-hand winding of relay 209 to conductor 357 which also extends to ground connected to the armature of relay 121. The armature of relay 209 will be actuated to connect with its lower contact 242. The armatures of relays 116, 117 and 118 will all be actuated to engage with their upper contacts. As a result of this the armatures of relays 301, 201 and 202 will all engage their upper contacts. Under this condition the first and second selecting circuits will cooperate as heretofore described to select the .00 lamp in the hundredths lamp bank 450. When the armature of relay 202 engages with contact 227 the third selecting circuit will connect ground to the right-hand terminals of units lamps 440 and 445 corresponding to units 0 and 5. With the armatures of relays 204 and 209 actuated to engage their respective lower contacts a circuit may be traced from battery through the armature of relay 204, contact 232, armature of relay 209, contact 242, contact 292 and the winding of relay 424 to ground closing the contacts of relay 424.

The armature of relay 08 in the fifth selecting circuit was actuated to its lower position to close contact 240 when the measuring instrument was in the position corresponding to 15 units. The armature of relay 208 remains locked in this position. A circuit may therefore be traced from battery through the armature of relay 208, contact 240 and contact 216 to parallel branches. One of the parallel branches extends through contact 435 which connects to the left-hand terminals of units lamps 440 to 444. Lamp 440 corresponding to the 0 units lamp will therefore light. The second parallel branch extends through contact 434 and the filament of lamp 428 to ground lighting lamp 428. Lamp 428 is the 20 tens lamp. The lighting of this combination of lamps indicates that the measuring instrument is set in the 20.00 position.

For the 25.00 position of the measuring instrument reference to vertical column 725 of Fig. 7 indicates that cam 114 only closes its contact. As a result of this the armature of relay 119 is actuated to its lower position closing contact 136. The armatures of relays 116, 117, 118 and 120 are all operated to their upper positions. The cooperation of the first and second selecting circuits again effects the selection of .00 lamp in the hundredths lamp bank. The third selecting circuit connects ground to the right-hand terminals of units lamps 440 and 445 in the same manner as heretofore described. The armature of relay 204 in the fourth selecting circuit will be actuated to its lower position to close contact 232. The armature of relay 209 in the fourth selecting circuit will be actuated to its upper position to close contact 241. A circuit may be traced which extends from battery through the armature of relay 204, contact 232, armature of relay 209, contact 241, contact 294 and the winding of relay 425 to ground closing the contacts of relay 425. The armature of relay 208 in the fifth selecting circuit remains locked in engagement with contact 240. A circuit may be traced from battery through the armature of relay 208, contact 240 and contact 216 to parallel branches. One parallel branch extends through contact 491 which connects to the left-hand terminals of units lamps 445 to 449 in parallel. Units lamp 445 corresponding to 5 units will therefore light. The second parallel branch extends through contact 438 and the filament of lamp 428 to ground lighting lamp 428. Lamp 428 as explained is the 20 tens lamp. The lighting of this combination of lamps indicates that the measuring instrument is in the 25.00 position.

It is pointed out that in the description above of the operation for the 00.00 position it was stated that the armatures of the relays were in the positions indicated, but the manner in which the armatures of the relays in the second, third, fourth and fifth selecting circuits were operated to these positions was not explained. This will now be made clear.

Reference to vertical columns 500, 600 and 700 in Figs. 5, 6 and 7 shows that for this condition, cams 106, 111 and 112 close contacts 161, 169 and 170. The armatures of relays 121 and 116 will be operated to their lower positions. The armatures of all other relays in Fig. 1 will be operated to their upper positions. Positive battery is therefore impressed through the left-hand windings of each of the relays in the second, third, fourth and fifth selecting circuits. Since the armature of relay 121 is down the usual return path to ground for the operation of the relays in the second, third, fourth and fifth selecting circuits is open. For this condition an alternate path extends from conductors 355, 356 and 357 through contacts 148, 149 and 150 respectively. A chain circuit is established through these contacts which connects each of these conductors to conductors 347. The left-hand winding of relay 208 also connects to conductor 347. Conductor 347 extends through contact 321, armature of relay 304, contact 319, armature of relay 303, contact 317 and the armature of relay 301 to ground. The armatures of all of the relays in the second, third, fourth and fifth selecting circuits are therefore operated to their upper positions. As a result of this relay 423 is operated. The cycle may then be repeated.

Relays 221, 222, 223 and 224 are maintained in the positions shown at all times in the present invention. It was pointed out that the present invention is arranged to measure increasing quantities. A rotational control circuit 500, which is not part of this invention, is indicated by a rectangle. By means of the rotational control circuit which connects to all five selecting circuits and control relays 221 to 224 the circuit herein may be modified to measure both increasing and decreasing quantities. However, this feature is not part of the present invention and no claims are directed to it hereunder.

What is claimed is:

1. A plurality of selecting devices connected in parallel to a single transmitter, means for transmitting a single permutation code signal combination from said transmitter to said devices simultaneously, means for effecting ultimate selections by said devices in response to the cooperative action of a plurality of signal elements of said combination and means for simultaneously effecting ultimate selections by said devices in response to single signal elements of said combination.

2. A single permutation code signal transmitter connected to a plurality of selecting devices arranged in parallel, means for transmitting permutation code signal combinations from said transmitter to said devices simultaneously, means in said devices for identifying each of the digits of any number from 0 to 100, inclusive, means in said devices for effecting selections by said devices in response to the cooperation of at least three signal elements of a multi-element permutation code signal combination at a first time and means for controlling said devices individually in response to the condition of individual signal elements of a permutation code signal combination at a second time.

3. A single permutation code signal transmitter, means connected to said transmitter for transmitting permutation code signal combinations to four separate independent selecting devices connected in parallel to said transmitter, means for effecting selections by one of said devices in response to the cooperative action of a group of elements of a single permutation code signal combination at a first time, and means for simultaneously controlling a group of said devices individually to effect a separate independent ultimate selection by each one of said group of devices in response to the condition of separate individual elements only of said permutation code signal combination at said first time.

4. In a permutation code signaling system, a first, second and third transmission channel, means for impressing either of two electrical conditions on each of said channels to form permutation code signals, a first selecting device comprising a switch selectively operable to either of two positions connected to said first channel only, a second selecting device independent of said first device comprising two switches each selectively operable to either of two positions connected individually to said first and said second channel, a third selecting device independent of each of said other devices comprising three switches each selectively operable to either of two positions connected individually to said first, second and third channels, and means for effecting three separate independent ultimate selections simultaneously through paths through said switches in each device in response to a single multielement permutation code signal combination impressed on said channels.

5. In a permutation code signal data transmission system for transmitting code signals corresponding to numbers defining measurements by a data measuring instrument, a first, second and third set of cams, means responsive to the operation of said instrument for operating said cams, a first, second and third set of contacts, means responsive to the operation of said respective sets of cams, for arranging each of said respective sets of contacts so that each set forms permutation codes defining a separate portion of a mulitdigit number corresponding to a measurement made by said instrument, a plurality of separate signal transmission channels, means for connecting said channels to said first set of cams so as to transmit permutation code signals defining a first portion of said number at a first time, means for connecting said channels to said second set of cams so as to transmit permutation code signals defining a second portion of said number at a second time, means for connecting said channels to said third set of cams so as to transmit permutation code signals defining a third portion of said number at a third time and means for defining a first portion of a number and a second portion of a number by means of a portion of a permutation code and defining the third portion of a number by the remaining portions of a code when said channels are connected to said third set of cams to define the corresponding complete setting of said measuring instrument at a fourth time.

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