

Aug. 13, 1946.

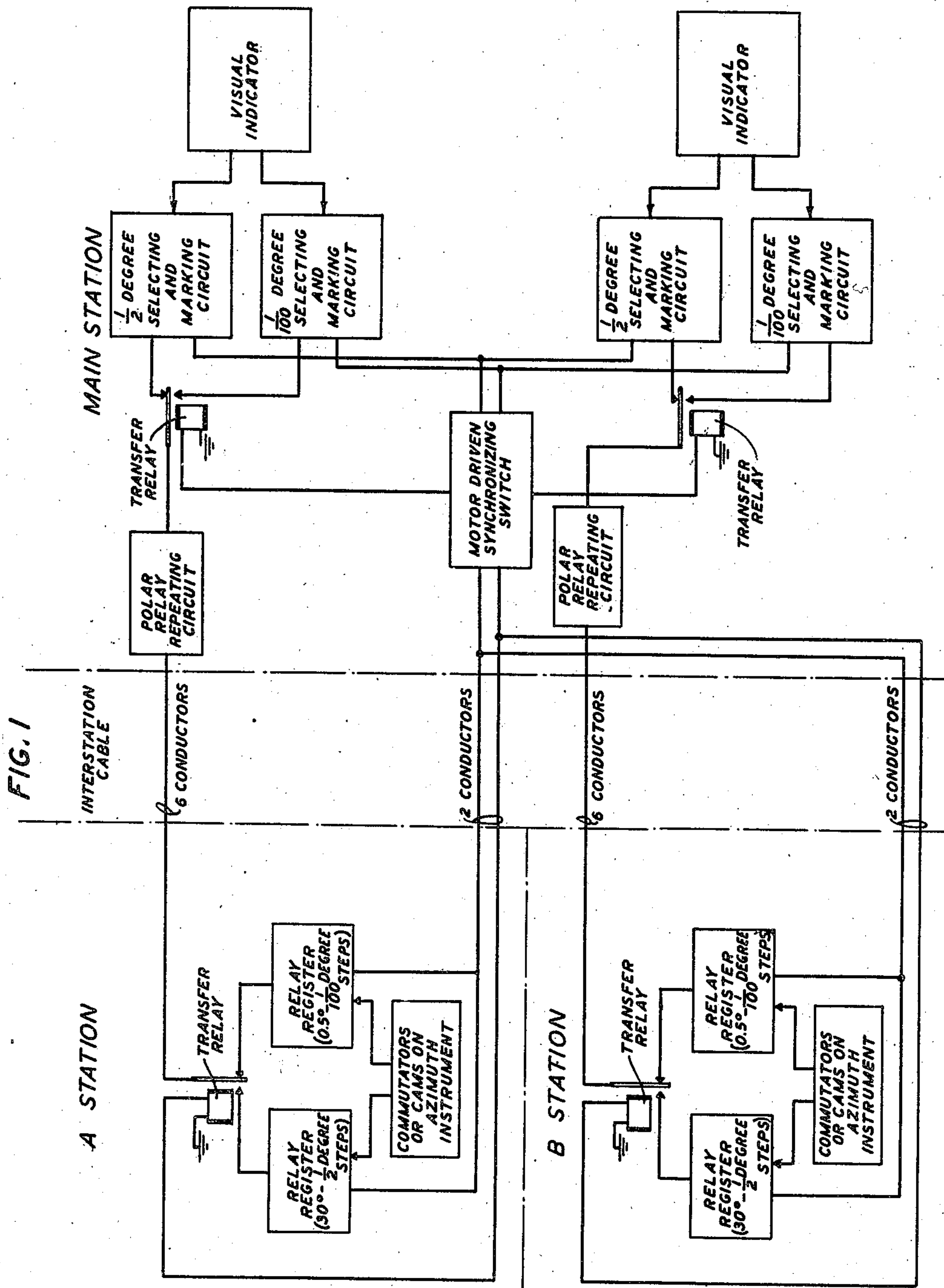
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2,405,617

DATA TRANSMISSION SYSTEM

Filed Dec. 15, 1942

10 Sheets-Sheet 1



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FIG. 2

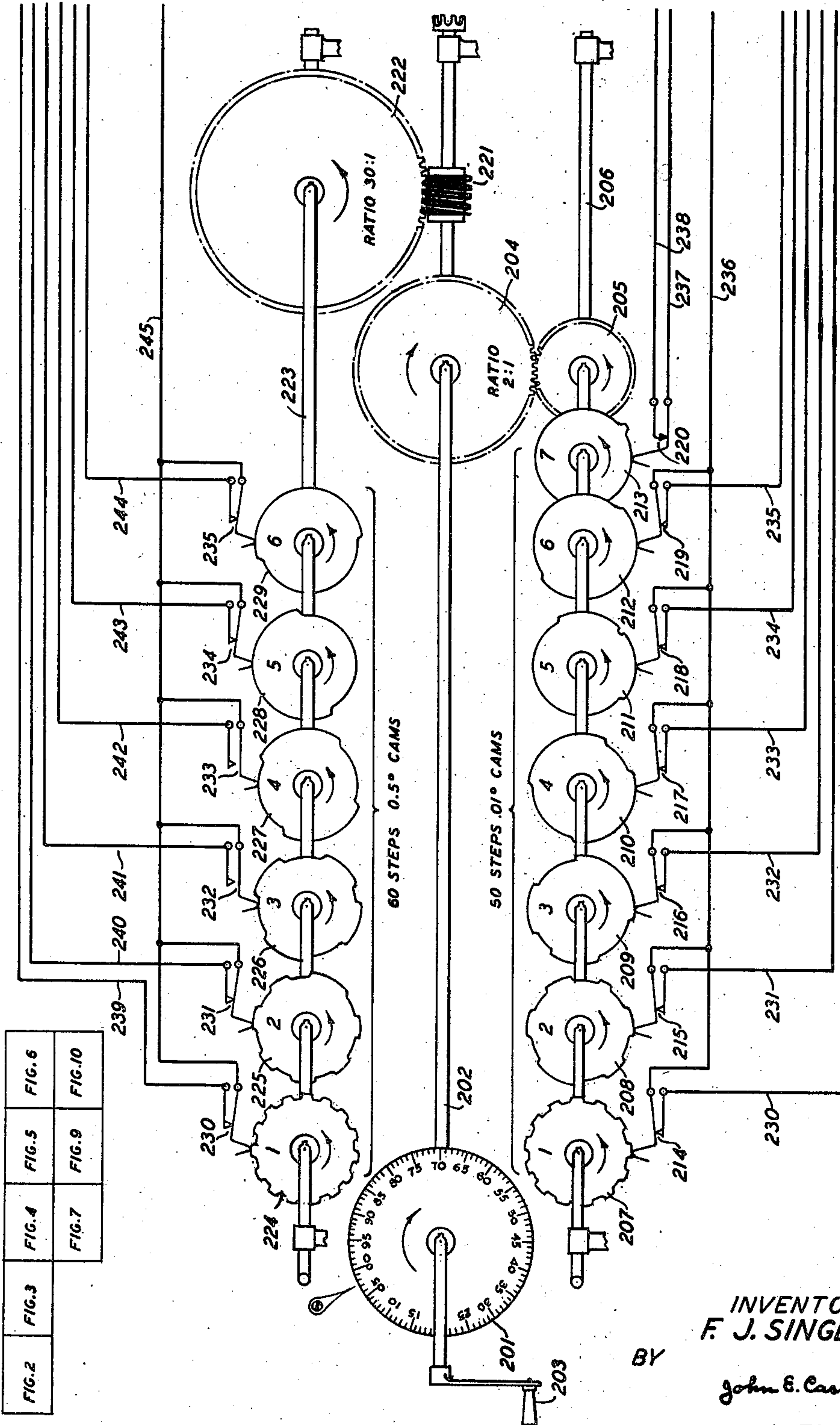


FIG. 1A

FIG. 2	FIG. 3	FIG. 4	FIG. 5	FIG. 6
	FIG. 7	FIG. 9	FIG. 10	

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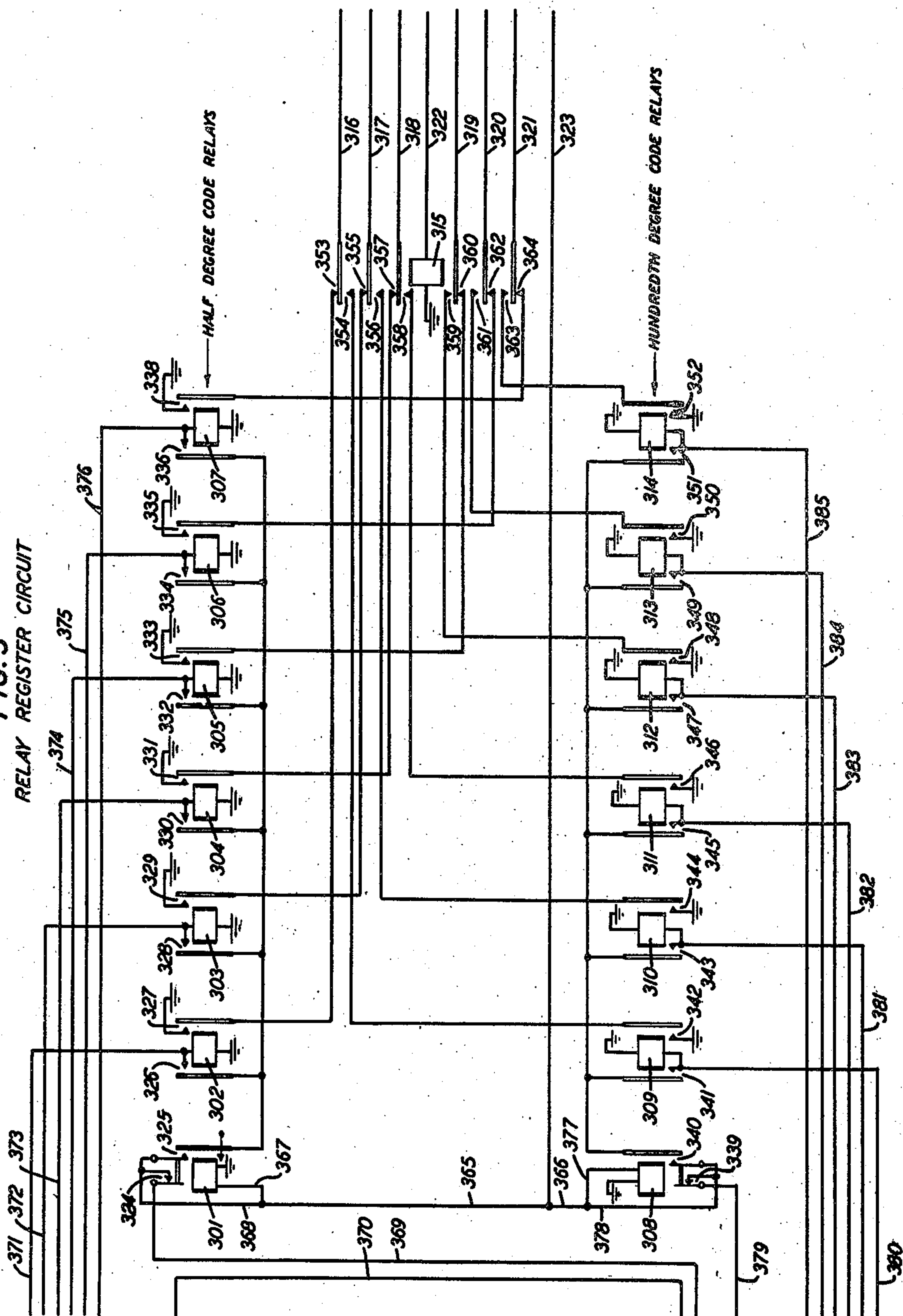
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FIG. 3
RELAY REGISTER CIRCUIT



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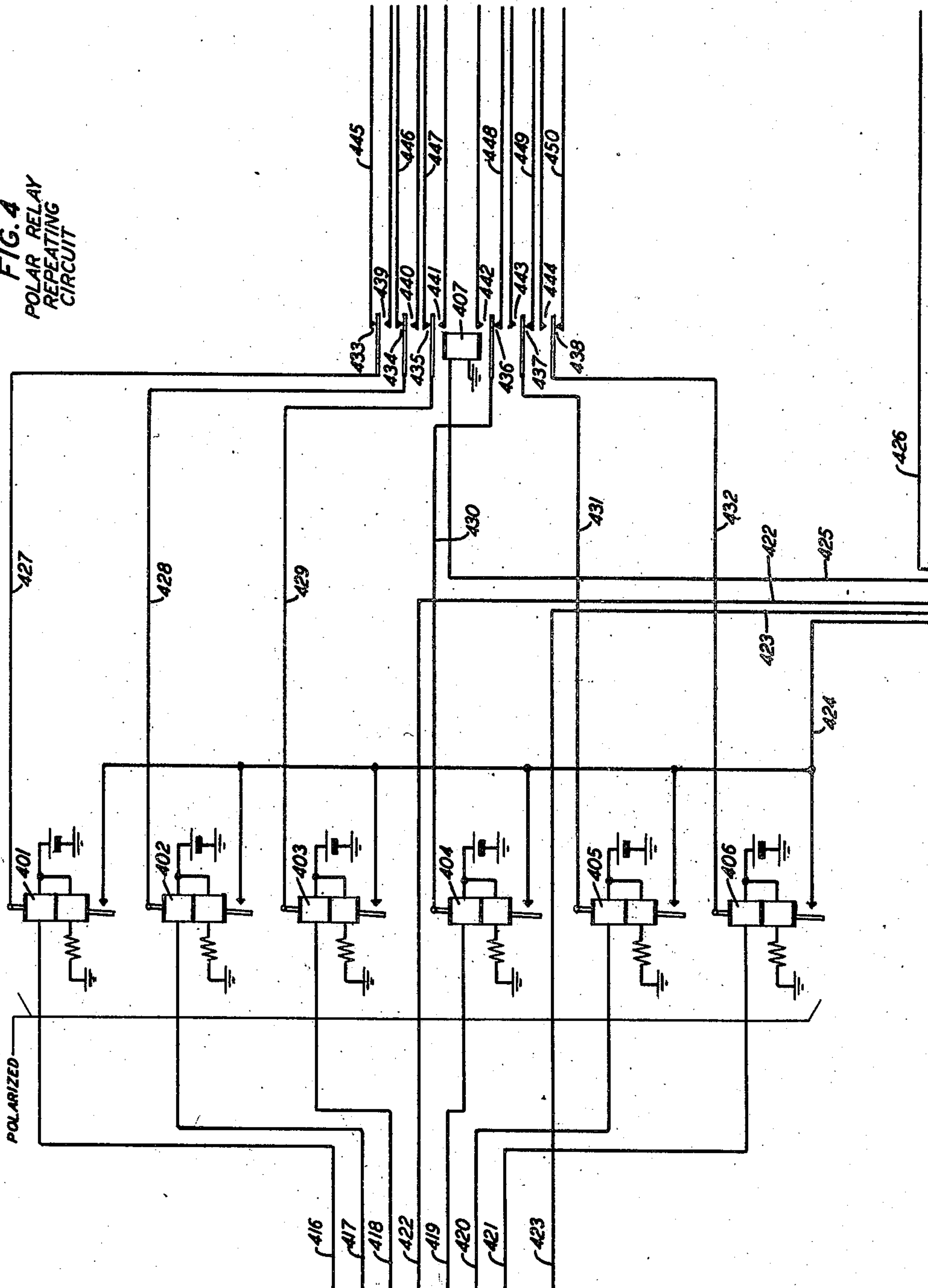
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FIG. 4
POLAR RELAY
REPEATING
CIRCUIT



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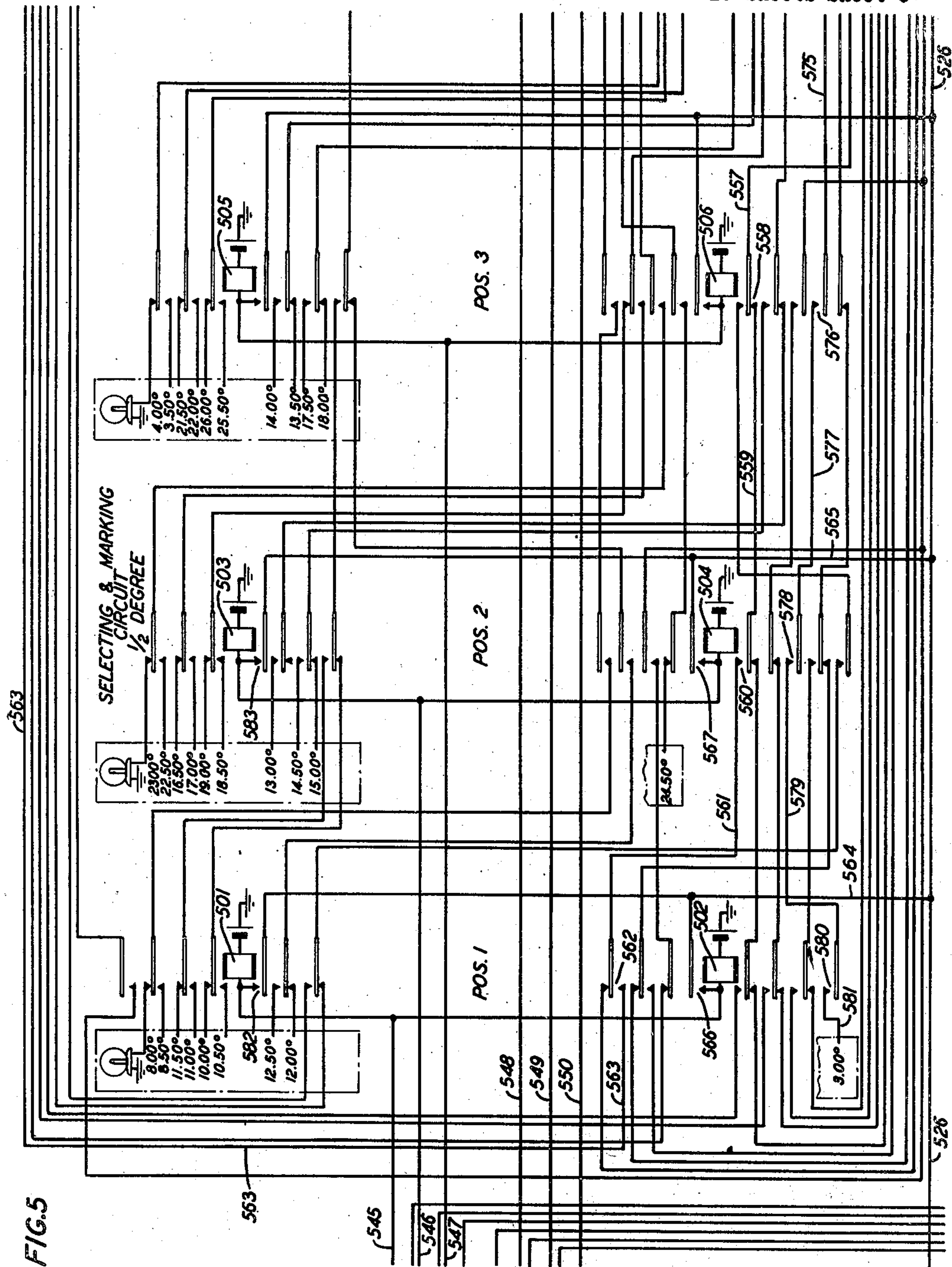
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DATA TRANSMISSION SYSTEM

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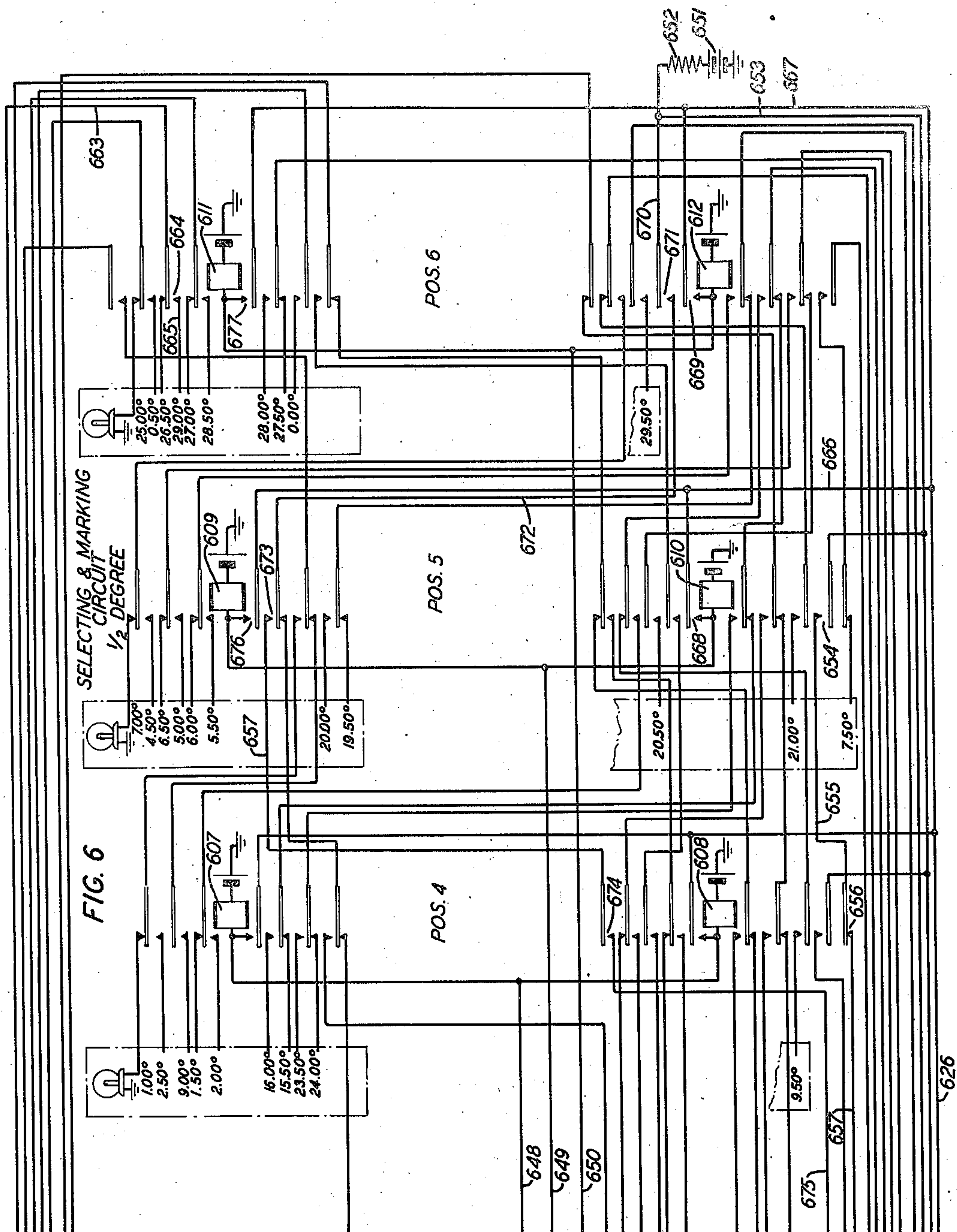
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10 Sheets-Sheet 6



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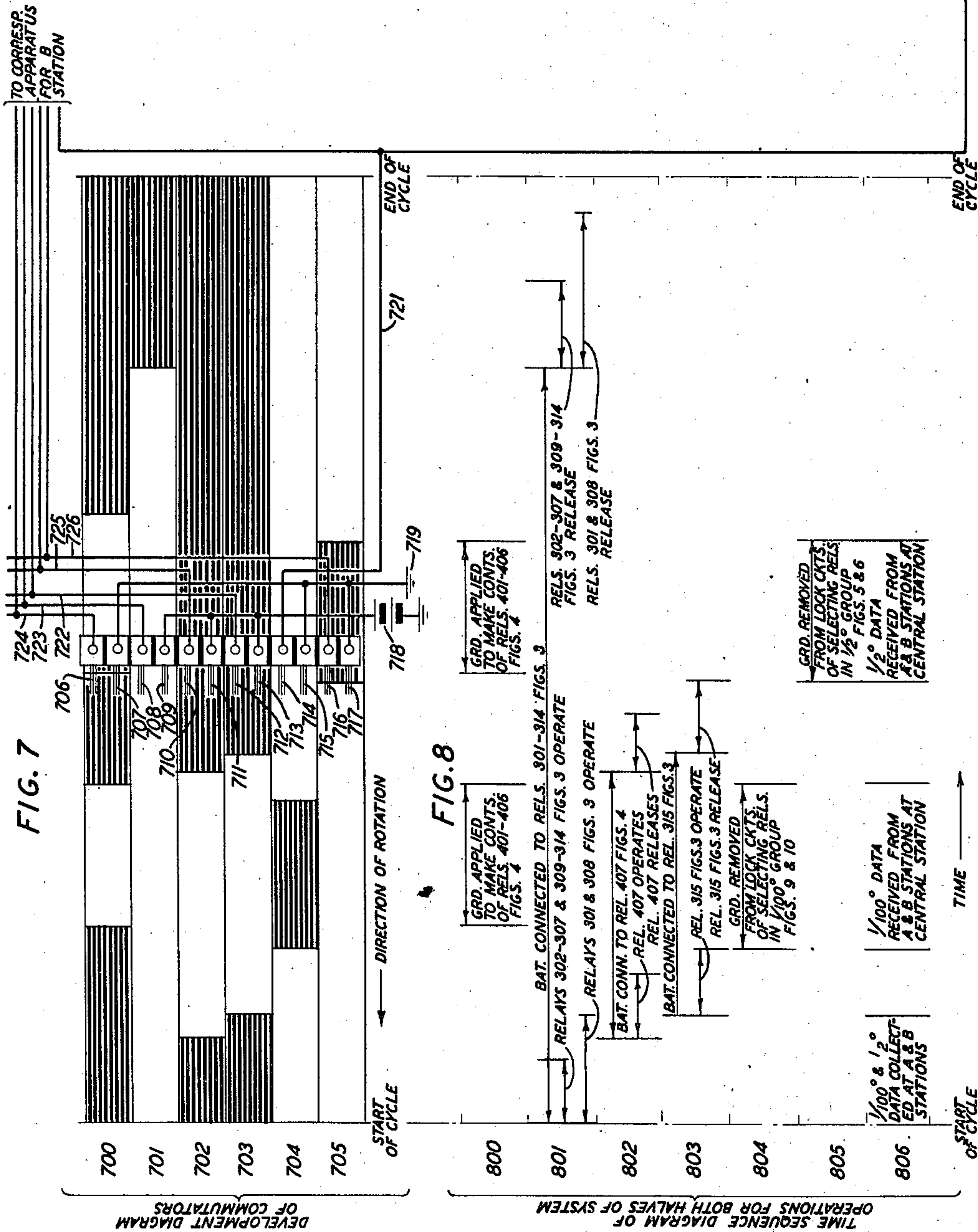
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DATA TRANSMISSION SYSTEM

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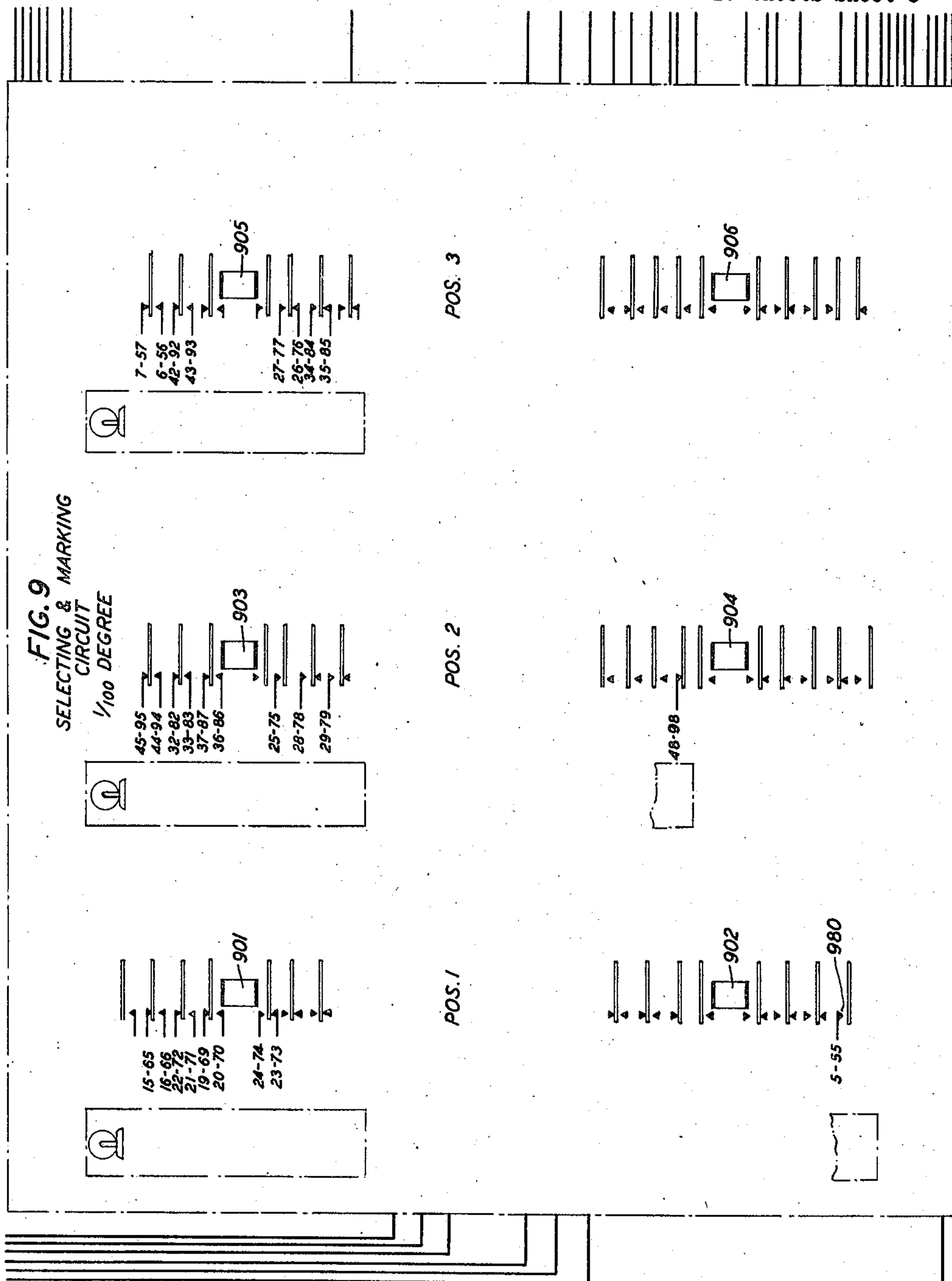
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DATA TRANSMISSION SYSTEM

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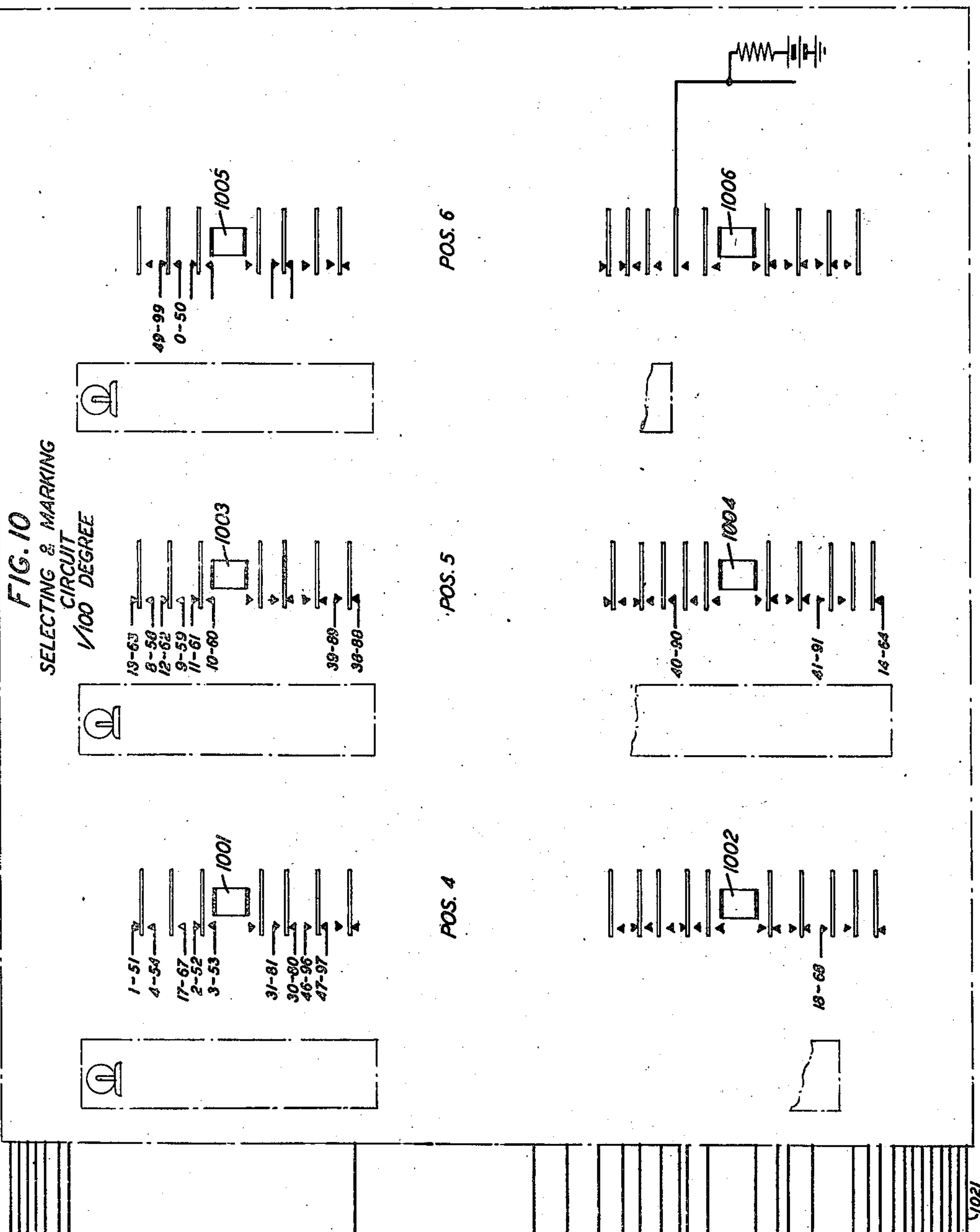
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DATA TRANSMISSION SYSTEM

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FIG. 11

60 STEPS $\frac{1}{2}^\circ$ EACH

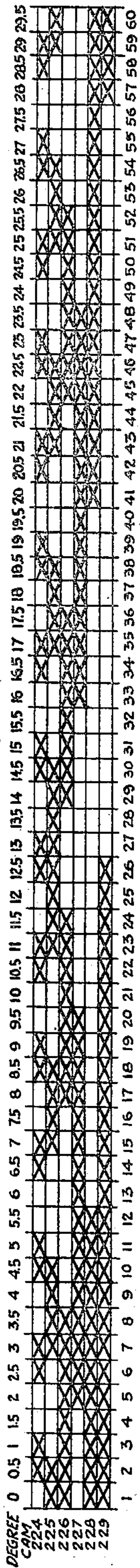


FIG. 12

50 STEPS $\frac{1}{100}^\circ$ EACH

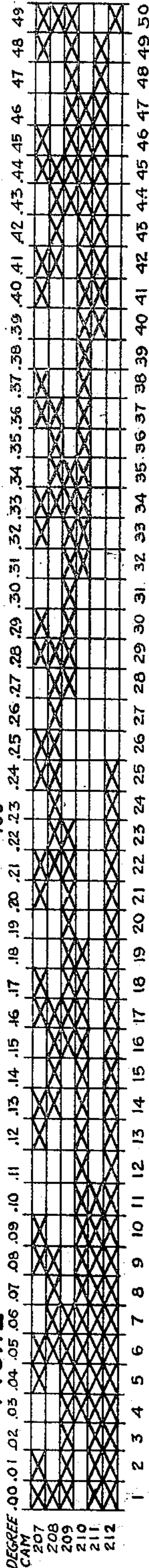


FIG. 13

CODE TABLE FOR HALF DEGREES

CODE COMBINATION	NUMBER OF SELECTED POINT (DEGREES)	POSITION OF LAMP SELECTING RELAY IN CIRCUIT	CODE COMBINATION	NUMBER OF SELECTED POINT (DEGREES)	POSITION OF LAMP SELECTING RELAY IN CIRCUIT
2356	0.00°	6	13	15.00°	2
12356	0.50°	6	3	15.50°	4
1356	1.00°	4	34	16.00°	4
356	1.50°	4	134	16.50°	2
3456	2.00°	4	1234	17.00°	2
13456	2.50°	4	234	17.50°	3
123456	3.00°	1	24	18.00°	3
23456	3.50°	3	124	18.50°	2
2456	4.00°	3	14	19.00°	2
12456	4.50°	5	4	19.50°	5
1456	5.00°	5	45	20.00°	5
456	5.50°	5	145	20.50°	5
46	6.00°	5	1245	21.00°	5
146	6.50°	5	245	21.50°	3
1246	7.00°	5	2345	22.00°	3
246	7.50°	5	12345	22.50°	2
2346	8.00°	1	1345	23.00°	2
12346	8.50°	1	345	23.50°	4
1346	9.00°	4	35	24.00°	4
346	9.50°	4	135	24.50°	2
36	10.00°	1	1235	25.00°	6
136	10.50°	1	235	25.50°	3
1236	11.00°	1	25	26.00°	3
236	11.50°	1	125	26.50°	6
26	12.00°	1	15	27.00°	6
126	12.50°	1	5	27.50°	6
12	13.00°	2	56	28.00°	6
2	13.50°	3	156	28.50°	6
23	14.00°	3	1256	29.00°	6
123	14.50°	2	256	29.50°	6
1		2	4		5
		3			6

TABLE 1

CODE TABLE FOR HUNDREDTHS OF A DEGREE

CODE COMBINATION	NUMBER OF SELECTED POINT (HUNDREDTHS OF A DEGREE)	POSITION OF LAMP SELECTING RELAY IN CIRCUIT	CODE COMBINATION	NUMBER OF SELECTED POINT (HUNDREDTHS OF A DEGREE)	POSITION OF LAMP SELECTING RELAY IN CIRCUIT
12356	0.850	6	12	23.275	2
1356	1.851	4	2	26.876	3
356	2.852	4	23	27.877	3
3456	3.853	4	123	28.878	2
13456	4.854	4	13	29.879	2
123456	5.855	1	3	30.880	4
23456	6.856	3	34	31.881	4
2456	7.857	3	134	32.882	2
12456	8.858	5	1234	33.883	2
1456	9.859	5	234	34.884	3
456	10.860	5	24	35.885	3
46	11.861	5	124	36.886	2
146	12.862	5	14	37.887	2
1246	13.863	5	4	38.888	5
246	14.864	5	45	39.889	5
2346	15.865	1	145	40.890	5
12346	16.866	1	1245	41.891	5
1346	17.867	4	245	42.892	3
346	18.868	4	2345	43.893	3
36	19.869	1	12345	44.894	2
136	20.870	1	1345	45.895	2
1236	21.871	1	345	46.896	4
236	22.872	1	35	47.897	4
26	23.873	1	135	48.898	2
126	24.874	1	1235	49.899	6
1		2	4		5
		3			6

TABLE 2

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UNITED STATES PATENT OFFICE

2,405,617

DATA TRANSMISSION SYSTEM

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Application December 15, 1942, Serial No. 469,045

7 Claims. (Cl. 177—351)

1

This invention relates to data transmission or telemetric systems and more especially to such systems in which data observed at the observing station is translated into permutation code telegraph signals which are transmitted from the observing to the receiving station for re-translation.

In the particular embodiment disclosed herein, the invention is applied to the transmission of data defining the angle between the line of sight to a target and a base line. Two observing stations at the extremities of a base line of known lengths are employed. Mechanism is provided for measuring the angle between the base line and the line of sight to the target at each observing station. The size of the angle is expressed in degrees and hundredths of a degree. The number expressing the angle is divided into two parts. A separate permutation code is assigned to each of the two parts. A group of permutation code signals, corresponding to the code defining one part of the number, such as the two right-hand digits of the number, is impressed simultaneously on a circuit connecting the observing and receiving stations. That is to say, the complete multielement permutation code signal is impressed on a circuit having as many separate transmitting elements as there are elements in the multielement permutation code employed. If, as herein, a six-element permutation code is employed for one portion of the number, a circuit capable of transmitting six signals simultaneously to define the two right-hand digits of the number completely are transmitted simultaneously. Then the signal elements comprising the code defining the left-hand digits of the number are impressed on the same connecting circuit in the same manner. At the receiving station two separate independent receiving means are employed to receive the signals from each observing station. The invention includes means for insuring that the two separate observing and receiving systems are operated in synchronism. The base line of fixed known length and the two angles between the base line and the two lines of sight from the two observing stations to the target fix the location of the target. The system is arranged to define to the hundredths of a degree any angle within a 30-degree zone but is capable of expansion. The particular 30-degree zone in which the line of sight is located is made known to the operators at the receiving station by means of some complementary facility such as by telephone or telegraph. Although the invention is applied herein to the measurement of

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angles, it may be employed for transmitting and receiving data representing anything without limit.

An object of the invention is the improvement of data transmission systems.

A more particular object of the invention is the improvement of data transmission systems in which permutation code telegraph signals are employed in transmitting the data between stations.

A still more particular object of this invention is the provision of a data transmission system arranged to rapidly transmit signals defining multi-digit numbers.

A feature of this invention is means for supplying all of the electric energy required for the operation of the system from the receiving station so that no means for producing electric energy is required at the observing station.

A further feature of this invention is the employment of means for generating telegraph signals in accordance with two completely independent permutation codes and in which signals in accordance with one or these codes define the two right-hand digits of a four-digit number representing observed data and signals in accordance with the second of these codes define the two left-hand digits of the number.

A further feature of this invention is an arrangement in which any of 4,096 numbers may be defined by permutation telegraph signals in accordance with two independent six-element codes but in which the apparatus is arranged for the actual transmission and translation of 3,000 of the possible 4,096 codes to identify any of 3,000 numbers which may represent any part of a 30-degree angle defined to the hundredths of a degree.

A further feature of this invention is an arrangement in which a change in the data to be transmitted is from one number to the next higher or next lower number and in which a corresponding change in the permutation code signals transmitted involves a change in but one element of each of the two multielement signal codes used to identify the number, which results in effecting changes in the transmitting and receiving apparatus with a minimum of signal transmission and readjustment.

A further feature of the invention is that all of the elements of a particular signal code combination completely defining one portion of the multidigit number corresponding to the observed data are impressed on the circuit interconnecting the stations at one time and all of the elements

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of a particular signal code combination completely defining another portion of the number are impressed on the circuit at a second time.

A further feature of the invention is that each set of data is entirely independent of previous data. That is, the system does not depend upon sequence nor history for information sent or decoded at a particular time, so that line hits or other disturbances will not result in errors in subsequently transmitted data.

These and other features of the invention will become apparent from the following description when read with reference to the associated drawings in which:

Fig. 1 is a schematic showing the general disposition of the major apparatus units of the entire system;

Fig. 2 shows two sets of transmitting cams which are mounted on the azimuth instrument at each observing station and on which the two codes corresponding to the two portions of a multidigit number representing the measured angle are set up at each observing station as well as the electrical contacts and wiring controlled by the cams at each station;

Fig. 3 shows two sets of relays on which the codes set up by the two sets of cams in Fig. 2 are impressed and a transfer relay for controlling the transmission of the data set up on each set of code relays to the receiving station at different times;

Fig. 4 shows a set of six polar relays located at the receiving station for receiving the codes set up on the two sets of code relays per Fig. 3 at different times. It includes also a transfer relay for controlling the directing of the two different codes defining the two different portions of the multidigit number to two different selecting and marking circuits which translates the two codes;

Fig. 5 represents the left-hand portion and Fig. 6 the right-hand portion of a relay selecting and marking circuit used in translating the codes set up on the top set of cams in Fig. 2 to identify the position of the line of sight in the observed 30-degree zone to the nearest half degree;

Fig. 7 is a commutator including six segmented drums each comprising conducting and non-conducting segments and a set of brushes for controlling the application of battery and ground to various apparatus units in the transmitting and receiving mechanisms associated with each observing and receiving device to control the transmission and reception of the two sets of permutation code signals used in defining any observed angle at each station in the proper time sequence;

Fig. 8 is a time sequence diagram for the commutator per Fig. 7 used in explaining the operation of the commutator;

Fig. 9 is the left-hand portion and Fig. 10 is the right-hand portion of a circuit which is identical with the circuit per Fig. 5 and Fig. 6. It is used to translate the codes set up on the bottom set of cams in Fig. 2 to fix the line of sight to the nearest hundredth of a degree by making the selection of a particular one of fifty possible one-hundredths of a degree in each one-half degree zone. Since Fig. 9 and Fig. 10 are identical with Fig. 5 and Fig. 6 and the manner in which they operate is the same as Fig. 5 and Fig. 6, the wiring of Fig. 9 and Fig. 10 is not shown in detail as it is not necessary to an understanding of the invention which may be fully understood from

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the description herein of the operation of Fig. 5 and Fig. 6;

Fig. 11 is a chart showing the manner in which the set of six cam-controlled contacts in the upper portion of Fig. 2 operates to transmit 60 codes defining 60 one-half degree angles. In this chart there are six horizontal rows, one for each of the six cams. There are 60 vertical rows, one for each of the 60 different cam settings. Where a rectangle is cross-hatched, it indicates that the corresponding cam has a raised surface in that particular position and that its corresponding contact is closed;

Fig. 12 is a chart showing the manner in which the set of six cam-controlled contacts in the lower portion of Fig. 2 operates to transmit 50 codes defining 50 one-hundredth of a degree angles. In this chart, there are six horizontal rows, one for each of the six cams. There are 50 vertical rows, one for each of the 50 different cam settings. Where a rectangle is cross-hatched, it indicates that the corresponding cam has a raised surface in that particular position and that its corresponding contact is closed;

Fig. 13 shows two code tables, one for half degrees and one for one-hundredths of a degree used in explaining the invention; and

Fig. 14 shows the manner in which Figs. 2, 3, 4, 5, 6, 7, 9 and 10 should be arranged each with relation to the other so that they may be properly interconnected into an operative system. The conductors extending to the margins of each of these figures interconnect to conductors in corresponding positions on contiguous figures.

In the system of numbering of the apparatus and wiring shown on these figures, apparatus and wiring in Fig. 2 will be numbered in the 200 series, apparatus and wiring in Fig. 3 will be numbered in the 300 series, etc.

Refer to Fig. 1. Fig. 1 shows in schematic form the general arrangement of the major apparatus units of a complete system comprising two observing stations and one main station or receiving station. It is to be understood that the observing stations are actually located at the extremities of a straight base line of fixed length passing through the receiving station. In Fig. 1, the two observing stations are shown for convenience at the left of the figure. At the upper left of the figure the main items of apparatus located at one station, labelled the A station, are shown. At the bottom left of the figure the major apparatus units at a second station, the B station, are shown. Each of the observing stations is connected to the receiving station by eight conductors. Six of these conductors are used for transmitting simultaneously the six-element permutation code signals. The remaining two conductors are used for synchronizing and controlling transmission.

As indicated in the upper and lower left-hand portions of Fig. 1, at each of the stations there are cams mounted on the azimuth instrument. As the line of sight to a target changes, the cam settings are changed. On each azimuth instrument, as indicated in Fig. 2, there are two sets of cams. One set of cams sets up 60 codes to define each of 60 one-half degree angles in a 30-degree zone. The other set of cams sets up 50 codes to define each of 50 one-hundredths of a degree in a half degree zone. At the main station there is a motor-driven synchronizing switch or commutator indicated by a rectangle in the middle of the right-hand portion of Fig. 1. The motor-driven synchronizing switch or commuta-

tor (1) maintains the transmission and reception of the data for each station in synchronism; (2) controls the operation of a transfer relay at each observing station which transfers the six code signal transmitting conductors, interconnecting an observing station and the central station, between two different sets of code registering relays at each observing station, which relays respond to the codes set up on the two sets of cams, so as to transmit each of the two codes defining each multidigit number to the receiving station in the proper sequence; (3) controls a second transfer relay individual to each observing station but located at the receiving station so as to direct the code signals defining the half degree information and the hundredth degree information to separate selecting and marking circuits in the receiving station for each observing station; (4) locks the code information received by the selecting circuit for the half degree information and the hundredth degree information momentarily in the selecting and marking circuits associated with each observing station at the receiving station.

Codes defining the particular half degree zone in which the line of sight to the target is located are impressed on the six code transmission conductors connecting each observing station with the main station simultaneously. The code defining the half degree zone is impressed on a polar relay repeating circuit at the main station individual to each observing station. The code set up on each polar relay repeating circuit for a particular one-half degree zone is impressed at the receiving station on an individual one-half degree selecting and marking circuit for each observing station which translates the code and operates an indicator to show the number of the particular one-half degree zone involved at the main station. After this information has been transmitted and recorded at the main station, the code for the hundredth of a degree information is transmitted from each observing station over the same six wires used to transmit the half degree information from each observing station to the receiving station. The hundredth of a degree information is set up at the receiving station on the same polar relay repeating circuit associated with each observing station used in receiving the one-half degree information. The polar relay repeating circuit transmits the code identifying the hundredth degree setting into an individual one-hundredth degree selecting and marking circuit for each observing station. The hundredth degree selecting and marking circuit controls an indicator to indicate the particular one-hundredth degree setting for each station.

Refer to Fig. 2. Fig. 2 shows the two sets of permutation cams mounted on the azimuth instrument at an observing station. Fig. 2 also shows a vernier 201 having 100 divisions. Each of the divisions represents one-hundredth degree. The vernier is rigidly secured to a shaft 202. The shaft and vernier are rotated by means of crank 203. The telescope on the azimuth instrument (not shown) is rotated through one degree for each revolution of crank 203 by means of gear 204 which is also rigidly secured to shaft 202.

Securely fixed to shaft 202 is worm gear 221 which engages with spur gear 222. The ratio of gears 221 and 222 is such that gear 222 makes one-thirtieth of a revolution for each revolution of gear 221 and vernier 201. One-thirtieth of

a revolution of gear 222 therefore corresponds to one degree change of azimuth and a complete revolution of gear 222 corresponds to a 30-degree change of azimuth. Gear 222 is securely fixed to shaft 223. Cams 224, 225, 226, 227, 228 and 229 are also securely fixed to shaft 223. Cams 224 to 229 control contacts 230, 231, 232, 233, 234 and 235. The cuttings of cams 224 to 229 are arranged so that they set up 60 different combinations on contacts 230 to 235 for each rotation of shaft 223. Each different setting of contacts 230 to 235 defines a different half degree in a 30-degree zone.

Rigidly secured to shaft 202 is gear 204 which engages gear 205 securely mounted on shaft 206. The ratio of gears 204 and 205 is such that for each revolution of shaft 202, while gear 204 rotates once, gear 205 rotates twice turning shaft 206 through two revolutions. Securely fixed to shaft 206 are cams 207, 208, 209, 210, 211, 212 and 213 which control contacts 214, 215, 216, 217, 218, 219 and 220. Since shaft 206 rotates twice for each rotation of the vernier, shaft 206 makes one revolution for each fifty-hundredths degree change of azimuth. Cams 207 to 212 are so cut that during each revolution of shaft 206 the cams set up 50 different combinations of settings of contacts 214 to 219. Each different combination of contact settings defines a different one-hundredth degree of azimuth.

Cam 213 and contact 220 act as a switch to control the circuits associated with the one-half degree cams so that when the vernier passes through 00 and 49 the one-half degree cam circuits are held open.

Refer to Fig. 11. The different settings of the contacts controlled by cams 224 to 229 are indicated in the chart of Fig. 11. Reference to the left-hand vertical column in the chart, per Fig. 11, indicates the manner in which contacts 230 to 235 associated with cams 224 to 229 are arranged in the first of the 60 different cam positions for the half degree zones which corresponds to the code for 0.0 degree. The left-hand column of the chart indicates that for this condition contacts associated with cams 225, 226, 228 and 229 are closed and that contacts associated with cams 224 and 227 are open. The condition of contacts 230 to 235 for each of the 60 cam cuttings defining each of the half degree zones from 0.0 degree to 29.5 degrees is indicated in its respective vertical column in the chart per Fig. 11.

Refer to Fig. 12. The 50 vertical columns in Fig. 12 indicate the condition of contacts 214 to 219 associated with cams 207 to 212, respectively. The left-hand vertical column in Fig. 12 shows that the contacts associated with cams 207, 208, 209, 211 and 212 are closed in the first of the fifty cam positions which corresponds to the code for .00 degree or .50 degree for each degree setting, depending upon the particular half degree zone in which the line of sight is located.

Attention is particularly called to an important characteristic of the codes disclosed in Fig. 11 and Fig. 12. Reference to either of these figures shows that the change in the cam settings and therefore, in the contacts which the cams control, involves a change in but a single cam and therefore a single contact for each transition from one setting to the next higher or next lower setting.

This also illustrated in Fig. 13, Tables 1 and 2. Table 1 refers to the half degree cams; Table 2 refers to the hundredths of a degree cams. Columns 1 and 4 of each of these tables show the number of the cams which are in position to close

contacts for each code position. Columns 2 and 5 of the tables show the half degree and hundredth degree information corresponding to the codes indicated in columns 1 and 4. In the selecting circuits, per Figs. 5 and 6 considered together and Figs. 9 and 10 considered together, the selecting relays are arranged in six vertical rows in each pair of figures, each row comprising two relays. For instance, there are three such vertical rows in Fig. 5, rows 1, 2 and 3; and three in Fig. 6, rows 4, 5 and 6. The numbers in columns 3 and 6 in code Tables 1 and 2, per Fig. 13, indicate the relay row position in Figs. 5 and 6 and Figs. 9 and 10 in which the selected lamp corresponding to the code in the first and third columns and to the degree numbers in the second and fourth columns will be found. This will now be explained in more detail.

The code combination in the top rectangle of column 1, Table 1, which pertains to half degrees is 2356. This indicates that the contacts associated with half degree cams 2, 3, 5 and 6 will be closed for the 0.00 degree code as shown in the top rectangle of column 2 of Table 1. The number 6 appearing in the top rectangle of the third column of Table 1 indicates that the lamp for the 0.00 half degree zone will be found connected to a relay in relay row position 6 which is shown at the right of Fig. 6. Reference to Fig. 6 shows that the lamp corresponding to the 0.00 zone is connected to the upper of the two relays in position 6.

Reference to Table 1 and Table 2 of Fig. 13 will disclose that there is a change in only one element in each code on transition to the next higher and next lower number.

Before beginning the description of the detailed operation of the system a further explanation of the function of the commutator, per Fig. 7, and its relation to the various circuits will be given in order to facilitate an understanding of the detailed description to follow.

The raised surfaces on the peripheries of cams 224 to 229 in Fig. 2 will supply battery transmitted from the commutator at the receiving station over one of the two control conductors through such of contacts 230 to 235 as are operated to the windings of corresponding relays in relay group 302 to 307 in Fig. 3. For each cam contact which is closed a corresponding relay in the group of relays 302 to 307 will be operated and locked. When contacts 214 to 219 are operated in accordance with a particular code, a corresponding relay in the group of relays 309 to 314 will be operated and locked. Interconnecting each observing station with the receiving station there are six transmission conductors, such as 316 to 321, and two control conductors, 322 and 323. The transmission conductors are terminated on individual armatures of transfer relay 315. The armatures of the two sets of code relays are connected to opposing contacts associated with each of the six armatures of transfer relay 315. The same six transmission conductors 316 to 321 are used to transmit and the same six receiving relays 401 to 406 at the receiving station are used to receive both the code signal impulses for the half degree and the hundredth degree settings for one observing station. Corresponding transmission conductors and receiving relays function for the second station. It is necessary in order to fix the position of the target that the angles between the line of sight and the base line at each observing station be measured and the corresponding code signal impulses be transmitted simultaneously. Further, it is necessary to insure that the half degree

code impulses and the hundredth code impulses be transmitted from each observing station to the receiving station in proper sequence.

This is performed in large part by the commutator, per Fig. 7. This commutator supplies either battery or ground, as required, at proper intervals to control the switching of relay 315 in Fig. 3 so as to connect the six conductors 316 to 321 either to the contacts of relays 302 to 307 for the transmission of the half degree code information, or to the contacts of relays 309 to 314 for the transmission of the hundredth degree information. After the codes for either the half degree information or the hundredth degree information are set up on relays 401 to 406 individual to each observing station, the commutator controls transfer relay 407 at the receiving station to direct the code information to the proper group of selecting and marking relays. It has been explained that there are two different selecting and marking circuits associated with each observing station, one for the half degree information and the other for the hundredth degree information. As this information is set up at different times on relays 401 to 406 in Fig. 4 at the receiving station, it is necessary to route it at the proper time to either the selecting and marking circuit for the half degree information or to the selecting and marking circuit for the hundredth degree information. Relay 407 controls the connection of Figs. 5 and 6 which taken together constitute the selecting and marking circuit for the half degree information, or of Figs. 9 and 10 which taken together constitute the selecting and marking circuit for the one-hundredth degree information to the code receiving relays 401 to 406. When Figs. 5 and 6 are connected through transfer relay 407 to the code receiving relays 401 to 406 in Fig. 4, relays corresponding to the particular code set up on the code receiving relays will be operated in Fig. 5 and Fig. 6 to make a selection of a particular indicator which in the present embodiment is a lamp. Some one of 60 lamps in Figs. 5 and 6 is lighted to indicate a particular half degree zone in the 30-degree range. When Figs. 9 and 10 are connected through transfer relay 407 to code receiving relays 401 to 406, a group of relays in Figs. 9 and 10, corresponding to the code set up on relays 401 to 406 in Fig. 4, will be operated to make a selection of some one of 50 lamps. The lighted lamp in Fig. 9 or 10 will indicate the particular fiftieth division on which the line of sight is located in the half degree zone shown by the lighted lamp in Fig. 5 or 6, thus determining the line of sight to the nearest hundredth of a degree.

The time of operation of the transfer relays for both stations is controlled simultaneously by the commutator in Fig. 7. The commutator also locks the various code and selecting relays momentarily to maintain their registrations for necessary intervals and to achieve one of the important objectives of this invention, to prevent unnecessary operation of relays on transitions.

The means by which the whole system is held in synchronism and the time sequence of operations may be understood from reference to Figs. 7 and 8.

Fig. 7 represents a commutator having six segmented rings 700 to 705 and twelve brushes 706 to 717. The segmented rings are shown in the developed condition. The rings are rotated in unison by a motor (not shown). As the six

rings rotate each engages a corresponding pair of stationary conducting brushes which are insulated each from the other. Thus, brushes 706 and 707 engage rings 700. Brushes 708 and 709 engage rings 701, etc. Ground 719 is connected to brushes 707, 715 and 717. Battery 718 is connected to brushes 709, 711 and 713. Each of the segmented rings comprises conducting and insulating segments. The conducting segments are represented by plain rectangles; the insulating segments are represented by shaded rectangles. As the rings are rotated, when a conducting segment is presented to its corresponding pair of brushes, battery or ground is transmitted from one of the pair of brushes through the conducting segment and the other of the pair of brushes to various items of apparatus at each of the A and B transmitting stations to insure their operation in synchronism and to control the order of transmission of the codes for the half degree and hundredth degree information from each observing station and their reception by the corresponding selecting and marking circuit for each station in the proper sequence.

Attention is especially called to the fact that the single six-ring commutator, per Fig. 7, controls the operation of the transmitting and receiving apparatus for both the A and B stations. The six time-control conductors 721 to 726, in Fig. 7, are shown connected to various items of apparatus in the different figures which are assumed to serve the A station. These same six conductors are extended to a bracket in Fig. 7 marked "To corresponding apparatus for B station" to indicate that they also serve the B station simultaneously. Fig. 8 is a time sequence diagram for Fig. 7. It indicates times when the battery or ground connection, as the case may be, is applied through the conducting segments of the rings, per Fig. 7, to the transmitting and receiving apparatus of stations A and B to maintain synchronism and the proper order of transmission and reception of the half degree and hundredth degree information. The time cycle is represented as starting at the left-hand margin of Fig. 8 marked "Start of cycle" and ending at the right-hand margin of Fig. 8 marked "End of cycle." The time of a full cycle is equal to the time for one complete rotation of the commutator, per Fig. 7, which is of the order of one one-twentieth of a second. It is pointed out that the line of sight to the target may change more slowly than one one-hundredth of a degree per one-twentieth of a second and may even remain stationary, in both of which cases the azimuth setting and corresponding codes will remain unchanged while the code impulses are repeated and the indicator settings will remain unchanged during a corresponding interval, although they will be checked once each cycle, or once each rotation of the commutators.

Time in Fig. 8 is measured from left to right. The direction of rotation of the commutator rings is represented by the arrow in Fig. 7. The brushes are shown in the middle of Fig. 7 rather than at the start of cycle position for convenience.

Commutator 700 applies ground intermittently over conductors 724 in Fig. 7, and 424 in Fig. 4 to each of the make contacts of polar relays 401 to 406 at the receiving station, which relays receive the permutation code signals from the observing station.

Commutator 701 applies battery intermittently over conductor 723 in Fig. 7, conductor 423 in Fig. 4 and conductor 323 in Fig. 3, to the windings of relays 301 and 303 at observing station A. Relay 301 controls the momentary locking of the six relays 302 to 307 on which the codes for the half degree zones are set up by the six cams 224 to 229. Relay 303 controls the momentary locking of the six relays 309 to 314 on which the codes for the hundredth degrees are set up by cams 207 to 212.

Commutator 702 supplies battery over conductors 725 in Fig. 7, and 425 in Fig. 4, to the winding of transfer relay 407 which controls the directing of the signal impulses for the half degree and hundredths degree codes, set up on relays 401 to 406 in Fig. 4, to their proper selecting and marking circuits, that is, either to Figs. 5 and 6 which serve for the half degree codes or to Figs. 9 and 10 which serve for the hundredth degree codes.

Commutator 703 supplies battery intermittently over conductor 722 in Fig. 7, conductor 422 in Fig. 4, and conductor 322 in Fig. 3, to the winding of transfer relay 315 at observing station A. Relay 315 switches the six code transmission conductors alternately from the half degree code relays 301 to 307 to the hundredth degree code relays 308 to 313 so that signal impulses in accordance with the half degree codes and hundredth degree codes may be transmitted from the observing station to the receiving station in their proper order.

Commutator 704 supplies ground intermittently over conductor 721 in Fig. 7 and conductor 921 in Fig. 9 to the locking armatures and windings of the six pairs of selecting relays for the hundredth degree lamps in Figs. 9 and 10. The details of the connection of conductor 921 to the locking paths of the six pairs of relays are not shown. The details are identical, however, with the connections of the locking paths for the six pairs of corresponding selecting relays for the half degree lamps in Figs. 5 and 6.

Commutator 705 supplies ground intermittently over conductor 726 in Fig. 7, conductor 426 in Fig. 4, conductor 526 in Fig. 5, and conductor 626 in Fig. 6 to the locking armatures and windings of the five pairs of selecting relays for the half degree lamps in Figs. 5 and 6.

Fig. 8 shows a time sequence diagram of operation for both halves of the system. Sections 800 to 805 of Fig. 8 are time diagrams which relate to rings 700 to 705 in Fig. 7 and the apparatus units controlled thereby. Section 806 relates to the time of collection of the one-hundredth degree and one-half degree information at the A and B stations and to the times of the reception of the data at the central station.

Detailed operation

The operation of the system will now be described for the case in which the A observing station azimuth instrument is at 29.05 degrees. Since the B observing station arrangements are identical with those of station A, the operation of the B station part of the system will not be described. It is apparent, however, that even though the method of collecting, transmitting and translating data for both halves of the complete system is identical, the angular positions of the instruments at the two stations would normally be quite different.

Starting at the beginning of the time cycle of the motor-driven synchronizing switch, Figs. 7

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and 8, and assuming that the position of the azimuth instrument at the A station is at 29.05 degrees, a circuit may be traced from battery 718 in Fig. 7 through brush 709, the conducting segment of ring 701, brush 703, conductor 723, conductor 423 in Fig. 4 and conductor 323 in Fig. 3 to parallel branches formed by conductors 365 and 366. The upper branch 365 extends also to parallel branches 367 and 368. Branch 367 continues through the winding of relay 301 to ground. Relay 301 is slow to operate. During the interval before it operates, the branch through conductor 368 extends through break contact 324 of relay 301 through conductor 369 which connects to conductor 237 in Fig. 2 and the circuit extends through contact 220 which is closed, conductor 238, conductor 370 and conductor 245. Conductor 245 is connected in parallel to the armatures actuated by the half degree cams.

Reference to Fig. 13, Table 1, columns 4 and 5, second line from the bottom, indicates that the code for 29 degrees on the half degree cams is 1256. Contacts 230, 231, 234 and 235 will therefore be closed. The closure of contact 230 establishes a circuit through conductor 239, conductor 371 and the winding of relay 302 to ground, operating relay 302. The closure of contact 231 establishes a circuit through conductor 240, conductor 372 and the winding of relay 303 to ground, operating relay 303. The closure of contact 234 establishes a circuit through conductor 243, conductor 375 and the winding of relay 306 to ground, operating relay 306. The closure of contact 235 establishes a circuit through conductor 244, conductor 376 and the winding of relay 307 to ground, operating relay 307.

Simultaneously with the operation of the half degree code relays the hundredth degree code relays are operated over the branch of the circuit connected to conductor 366. Conductor 366 extends to parallel branches 377 and 378. Branch 377 extends through the winding of relay 308 to ground but relay 308 is also a slow-to-operate relay. While it remains released a circuit may be traced through conductor 378, break contact 339 of relay 308, conductor 379, which connects to conductor 236 in Fig. 2 to the armatures of the hundredth degree cams in parallel.

Reference to Fig. 13, Table 2, columns 1 and 2, sixth line from the top, indicates that the code corresponding to five-hundredths is 123456. Contacts 214 to 219, inclusive, will therefore all be closed. Closure of these contacts establishes circuits through conductors 230 to 235 which connect to conductors 380 to 385, respectively, each of which extends to ground through the winding of a relay in the 309 to 314 group, operating each of these relays.

When relay 301 operates, the battery supplied from the commutator circuit heretofore traced is connected through conductor 368 and make contact 325 of relay 301 to the left-hand armatures and make locking contacts of operated relays 302, 303, 306 and 307 to maintain the code for 29 degrees on these relays. After relay 308 operates, battery is supplied through conductor 378 and make contact 340 of relay 308 to the left-hand armatures and locking make contact of each of relays 309 to 314, locking each of these relays to maintain the code for five-hundredths of a degree.

During the interval that the data is being set up on the coding relays, per Fig. 3, at the A station, relay 315 at that station is released because

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the circuit to battery through commutator 703, Fig. 4, is open. This is indicated by the shaded rectangle at the left-hand end of commutator ring 703 as well as by the time sequence diagram of Fig. 8. With relay 315 released, the right-hand armatures of the group of relays 302 to 307 are connected to the break contacts of relay 315. Those of relays 302 to 307 which have been operated, namely, relays 302, 303, 306 and 307, will connect ground through their right-hand armatures and the corresponding make contacts of relay 315, namely, contacts 353, 355, 362 and 364 to conductors 316, 317, 320 and 321. These circuits are extended to the receiving station where they connect to conductors 416, 417, 420 and 421 which extend through the top windings of polar receiving relays 401, 402, 405 and 406 to battery in each instance. Polar relays 401 to 406 are biased by obvious circuits extending through their bottom windings which maintain their respective armatures actuated toward the left when no current flows in their top windings. When the circuit through their top windings is energized, the armatures are actuated toward the right to engage their contacts. The armatures of relays 403 and 404 remain actuated to the left.

At this time, however, the coded information set up on the group of relays 401 to 406 is not transferred to the corresponding relays of the selecting and marking circuits for one-half degrees, per Fig. 5 and Fig. 6, because ground is disconnected by means of the insulating segment shown at the left of ring 700 in Fig. 7 from the circuit which may be traced from ground 719 through brush 707, insulating segment of ring 700, brush 706, conductor 724 and conductor 424 to the contacts of relays 401 to 406 in parallel. The coded data that was set up during the previous cycle of the synchronizing switch is, therefore, maintained on the relays, per Figs. 5 and 6, at this time.

After the coded data for 29.05 degrees has been collected on the relay register circuit, per Fig. 3, and concurrent with the completion of the operation of relays 301 and 308 in Fig. 3, synchronizing switch 7 moves to a position where commutators 702 and 703 apply battery, respectively, to the transfer relays, such as 407, corresponding to each observing station and to the transfer relay, such as 315, at each observing station. The circuit for relay 407 may be traced from battery 718, through brush 711, conducting segment of ring 702, brush 710, conductor 725, conductor 425, and the winding of relay 407 to ground, operating relay 407. The circuit for relay 315 may be traced from battery 718, through brush 713, conducting segment of ring 703, brush 712, conductor 722, conductor 422, over conductor 322 to the distant observing station and the winding of relay 315 to ground, operating relay 315. The operation of relay 315 transfers the six code transmission conductors 316 to 321 to the make contacts 354, 356, 358, 359, 361 and 363 which connect to the right-hand armatures of relays 309 to 314 and the circuits are extended through contacts 342, 344, 346, 348, 350 and 352 to ground. In this case impulses are transmitted over each of conductors 316 to 321 and all relays 401 to 406 operate.

Simultaneously with the operation of relays 401 to 406 in Fig. 4 the synchronizing switch moves to position where commutator 704 removes ground from the locking circuits of the relays which were operated for the previous one-

hundredth degree code in Figs. 9 and 10, thus enabling those relays to release and break down the hundredth degree code which had been set up by the previous cycle of the synchronizing switch. On the previous cycle the relays in Figs. 9 and 10 which had been operated in accordance with the code were locked over a circuit which extends from ground 719, through brush 715, conducting segment of ring 704, brush 714, conductor 721, conductor 921, and conductor 1021 which extends through a locking circuit of each of the operated relays in Figs. 9 and 10. The locking circuits on Figs. 9 and 10 are not shown in detail but they are identical with the locking circuits connected to conductor 526 in Fig. 5 which corresponds to conductor 921 in Fig. 9, and conductor 626 in Fig. 6 which corresponds to conductor 1021 in Fig. 10.

As the relays in Figs. 9 to 10 start to release, the synchronizing switch, per Fig. 7, moves to position where commutator ring 700 applies ground to the make contacts of relays 401 to 406 in Fig. 4. Application of these grounds closes paths from the respectively operated relays 401 to 406 to their corresponding relays in Figs. 9 and 10. Since each of relays 401 to 406 is operated, each of the relays in Figs. 9 and 10 will also be operated. Operation of all of the relays in Figs. 9 and 10 establishes a local circuit in these figures to light the .05 lamp which indicates that the line of sight of the azimuth instrument at observing station A is at .05 degree. After the relays in Figs. 9 and 10 have had time to fully operate, commutator 704 applies ground to the locking circuits of the relays and they, therefore, remain operated throughout the rest of the cycle of the synchronizing switch and the .05-degree indication is maintained. These circuits will not be traced at this time as Figs. 9 and 10 are not shown in detail. The detailed operation of these circuits to perform this function will be understood from the detailed description of the operation of the selective circuits per Figs. 5 and 6 hereunder.

Shortly after the locking path is established through commutator ring 704 of the synchronizing switch to the operated relays of Figs. 9 and 10 to maintain the registration for the .05-degree code, commutator 700 again removes ground from the make contacts of relays 401 to 406 in Fig. 4. This ground is removed in time to insure that when battery is removed from transfer relays 315 in Fig. 3 and 407 in Fig. 4 and relays 401 to 406 in Fig. 4 take up new positions for the one-half degree code, there will be no false code set up on the one-half degree or one one-hundredth degree selecting circuits per Figs. 5 and 6 and Figs. 9 and 10.

After the removal of the ground from the make contacts of relays 401 to 406 in Fig. 4, commutator ring 702 in Fig. 7 removes ground from transfer relay 407 in Fig. 4 and shortly thereafter commutator ring 703 removes ground from transfer relay 315 in Fig. 3 and these relays release. As soon as transfer relays 407 and 315 are released the 29-degree code set up on the half degree code relays, per Fig. 3, is transmitted to the receiving station and relays 401, 402, 405 and 406 operate.

Later after sufficient time has elapsed to insure the complete release of transfer relays 315 in Fig. 3 and 407 in Fig. 4 and the operation of relays 401, 402, 405 and 406 in Fig. 4, commutator 705 removes ground from the locking circuits of the one-half degree selecting circuit, per Figs. 5

and 6. The relays in these figures which were operated in accordance with the previous code attempt to release. Those of the operated relays which do not receive ground from the make contacts of the polar relays in Fig. 4 release; those that do receive ground from the make contacts of the polar relays in Fig. 4 remain operated. If the code which is received by the polar relays requires the operation of relays in Figs. 5 and 6 in addition to such of the relays as are maintained operated, such relays will receive ground and will be operated. For the 29-degree code the relays in positions 1 and 2 in Fig. 5 and in positions 5 and 6 in Fig. 6 operate, as the half degree code for 29 degrees, as has been explained, is 1256. Relays 501, 502, 503, and 504 in Fig. 5 and relays 609, 610, 611 and 612 in Fig. 6, therefore, operate. This will now be explained in more detail.

When transfer relays 315 and 407 are released and the conducting segment of commutator ring 700 is in engagement with brushes 706 and 707, a circuit may be traced from ground 719 through brush 707, conducting segment of ring 700, brush 706, conductor 724, and conductor 424 in Fig. 4, to the right-hand contacts of the polar relays 401 to 406 in parallel. In the case of relays 401, 402, 405, and 406 circuits are closed through their armatures and conductors 427, 428, 431 and 432, respectively, through contacts 433, 434, 437 and 438, respectively, through conductors 445, 446, 449 and 450, respectively, through conductors 545, 546, 549 and 550, respectively, each of which connects in parallel to the windings of a pair of relays in Fig. 5 or Fig. 6. Conductor 545 connects through the windings of relays 501 and 502 in parallel to battery. Conductor 546 connects through the windings of relays 503 and 504 in parallel to battery. Conductor 549 connects to conductor 649 in Fig. 6 which extends through the windings of relays 609 and 610 in parallel to battery. Conductor 550 connects to conductor 650 which extends through the windings of relays 611 and 612 in parallel to battery. All of these relays operate. A circuit may then be traced from battery 651 through resistance 652, conductor 653, contact 654, conductor 655, contact 656 and conductor 657 which connects to conductor 557 in Fig. 5. The circuit continues through contact 558, conductor 559, contact 560, conductor 561, contact 562 and conductor 563 which connects to conductor 663 in Fig. 6. The circuit continues through contact 664 and conductor 665 and is terminated at a point marked "29.00" which represents a circuit extending through the filament of a lamp to ground. The lamp lights to provide an indication that the line of sight of the azimuth instrument is in the 29.00° half degree zone.

If the relays in Figs. 5 and 6 are assumed to be operated in accordance with any of the code combinations for any of the sixty different half degree settings indicated in Fig. 13, Table 1, a circuit may be traced from battery 651 through make contacts on relays in positions corresponding to the particular code in Figs. 5 and 6 and through break contacts on relays in other positions to numbers corresponding to those shown in columns 2 and 5 of the table which represent corresponding indicating lamps in each instance.

After registration of the 29-degree setting on the half degree selector circuit, commutator 705 locks these relays momentarily over a circuit which may be traced from ground 719 through brush 717, conducting segment of ring 705, brush

716, conductor 726, conductor 426 in Fig. 4, conductor 526 in Fig. 5, and conductor 626 in Fig. 6 which connect to parallel branches 564, 565, 666 and 667. Branch 564 extends through operated contacts 566 and 582 and the windings of relays 502 and 501 in parallel to battery. Branch 565 extends through make contacts 567 and 583 to the windings of relays 504 and 503 in parallel to battery. Branch 666 extends through make contacts 668 and 676 and the windings of relays 610 and 609 in parallel to battery. Branch 667 extends through make contacts 669 and 677 and the windings of relays 612 and 611 in parallel to battery. Relays 501, 502, 503, 504, 609, 610, 611 and 612 will be locked to maintain the 29-degree code until commutator ring 705 interposes its insulating segment between its associated brushes.

Soon after the relays for the 29-degree code are locked in the operated position ground is removed from the make contacts of the polar relays in Fig. 4 when the insulating segment of ring 700 is interposed between brushes 706 and 707.

Finally the cycle is completed when the insulating segment of commutator ring 701 is interposed between brushes 708 and 709 to disconnect battery from the locking circuits of the half degree and hundredth degree code relays in Fig. 3, permitting these relays to release. The apparatus associated with stations A and B is then prepared to register and record the new position of the telescope at the A and B stations.

Attention is called to the fact that the fifty codes for the fifty one-hundredth degrees in each half degree, as shown in Table 2, starting at 0 and ending at 49 correspond to those shown for the half degrees in Table 1, starting at the code for 0.50 degree and ending at the code for 25.00 degrees. The code for five-hundredths degree, shown in Table 2, is 123456. This corresponds to the code for 3.00 in Table 1. A circuit corresponding to the circuit for the five-hundredth degree code in Figs. 9 and 10 may, therefore, be traced, by way of example, in Figs. 5 and 6. The circuit extends from ground through battery 651 in Fig. 6, resistance 652, conductor 670, contact 671, conductor 672, contact 673, conductor 657, contact 674, conductor 675 which connects to conductor 575 in Fig. 5, contact 576, conductor 577, contact 578, conductor 579 and contact 580 to conductor 581 which is terminated in a symbol for the 3.00-degree lamp. In Fig. 9 the conductor corresponding to conductor 581 would be terminated in the symbol 5 corresponding to the five hundredths of a degree lamp, as indicated in the sixth line, columns 1 and 2 of Table 2 and as shown for contact 980 of relay 902 of Fig. 9.

Attention is especially called to the fact that in the invention herein the entire multidigit number is defined for each cycle of operation. Notwithstanding the half degree azimuth zone may not change, the half degree code is transmitted once for each time the hundredth degree information is transmitted. The reason for this is to minimize the seriousness of trouble conditions such as "hits" affecting a code for any setting, particularly a half degree setting. If the setting for the half degree zone, were to remain unchanged, after having been once transmitted, while the line of sight of the azimuth instrument remained in a particular half degree zone, a transient trouble condition causing an erroneous half-degree setting would be much more serious than is the case when the entire half-degree and hundredth degree position is defined once per cycle and the frequency of transmission is relatively

high as in the arrangement herein. The system is practically proof against the effect of random hits as the effect of a hit would be so transient that it would be wiped out by the effect of the following cycle of operation practically before it could become apparent to the eye.

This is particularly important, as it eliminates practically the only difficulty inherent in permutation code data transmission systems so that full advantage may be taken of their characteristic superiority over other presently known systems, namely, that the received information is not seriously affected, as are present systems which depend upon balancing arrangements of impedance or voltage, by variations in line impedance due to changes in temperature and weather conditions.

What is claimed is:

1. A data transmission or communication system having a plurality of data stations connected to a central station, instrumentalities in said system for collecting complementary data simultaneously, said instrumentalities comprising a transmitter for transmitting synchronized impulses from said central station to said data stations, and control means at each of said data stations, responsive to the reception of said synchronizing impulses, for controlling the simultaneous transmission of all of the elements of a first and a second combination of multielement permutation code signals from each of said data stations to said central station at a first and a second time respectively, to define a first and a second portion of a multidigit number corresponding to a measurement at each of said data stations.

2. A data transmission or communicating system, a plurality of data stations and a central station in said system, a transmitter at said central station, means connected to said transmitter for transmitting first synchronizing impulses from said central station to said data stations, control means at said data stations, responsive to the reception of said impulses, for controlling the substantially instantaneous and simultaneous transmission of all of the elements of multielement permutation code signal combinations from each of said data stations to said central station, means at said central station for transmitting second synchronizing impulses to said data stations, and means at said data stations, responsive to the reception of said second impulses, for controlling the order of transmission of said permutation code signal combinations from said data stations to said central station.

3. In a data transmission system, an observing station, a first means thereat for establishing simultaneously first permutations of two electrical conditions to completely define a first portion, comprising two digits, of a multidigit number, a receiving station, a group of polar receiving relays at said receiving station, a multiconductor transmission circuit interconnecting said stations, means at said observing station for impressing first signals in accordance with said first permutations simultaneously on said circuit at a first time, a second means at said observing station for establishing simultaneously second permutations of two electrical conditions to completely define a second portion, comprising two digits, of said multidigit number, means for impressing second signals in accordance with said second permutations simultaneously on said circuit at a second time and other means at said receiving station, responsive to the reception of said first and

said second signals, for operating said relays in conformity with said first and second permutations.

4. In a data transmission system, an observing station, a receiving station, a transmission circuit interconnecting said stations, means at said observing station for impressing simultaneously on said circuit at a first time permutation signals in accordance with a first multielement code to completely define at least two digits forming a first portion of a multidigit number, means at said observing station for impressing simultaneously on said circuit at a second time permutation signals in accordance with a second multielement code, completely independent of said first code, to completely define at least two digits forming a second portion of said multidigit number, a single measuring device, at said observing station, for controlling both of said means, and means at said observing station for transmitting signals in accordance with said second code once for each time signals in accordance with said first code are transmitted so as to minimize the adverse effect caused by trouble conditions while said signals are being transmitted.

5. In a data transmission system, an observing station, a single measuring device at said station, a plurality of separate groups of electrical contacts controlled by said measuring device, means connected to said device for translating a measurement made by said device, expressible as a multidigit number, into a plurality of separate multielement permutation code combinations, in accordance with separate multielement permutation codes, means for adjusting all of the contacts in each of said groups of contacts simultaneously in accordance with said combinations, in response to said measurement, a single multichannel transmission circuit having a separate channel for each element in said codes connecting said station with a receiving station, means for impressing signals in accordance with all of said elements of one of said code combinations on said channels simultaneously at a first time to completely define a first group of two digits in said number, and means for impressing signals in accordance with all of said elements of another of said code combinations on said channels simultaneously at a second time to completely define another group of two digits in said number.

6. In a telemetric system, means for adjusting a measuring device to measure a quantity at an observing station in terms of a multidigit number having more than three digits, means for translating said measurement simultaneously into a

plurality of combinations of permutative settings of a plurality of groups of electrical contacts in accordance with a plurality of separate multielement permutation codes, to define each separate portion of said number, at least one of which portions has more than one digit, in response to said measurement, means for translating said plurality of permutative settings of said plurality of groups of electrical contacts into a plurality of separate code combinations of electrical signal elements, means for impressing each of said signal elements of each particular one of said code combinations simultaneously on a separate transmission channel in a single multichannel circuit interconnecting said observing station with a receiving station, and means for impressing said separate combinations on said circuit in sequence.

7. In a data transmission system, a first and a second observing station, a measuring instrument at each of said stations, means connected to each of said instruments for making measurements in an ordered numerical sequence, means connected to each of said instruments for translating each measurement by said instruments simultaneously into a first and a second six element permutation code signal combination, each combination corresponding to two consecutive digits of a four digit number defining each of said measurements, a receiving station, six individual conducting channels of a single transmission circuit interconnecting each of said observing stations individually with said receiving station, a synchronizing device at said receiving station, means connected to said synchronizing device for controlling each of said circuits simultaneously so as to impress on said channels simultaneously at a first time at said observing stations all six of the elements of a signal combination corresponding to the two right-hand digits of said four digit number defining a measurement at each observing station, means connected to said synchronizing device for controlling said circuits simultaneously so as to impress on said channels simultaneously at a second time at said observing stations all six of the elements of a signal combination corresponding to the two left-hand digits of said four digit number defining said measurement at each observing station, and means for impressing said combinations corresponding to said left-hand digits on said channels once for each time said combinations corresponding to said right-hand digits are impressed on said channels to minimize the effect of errors due to hits during transmission.

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