

April 26, 1960

A. P. JACKEL

2,934,754

CODE CONVERTERS

Filed Feb. 26, 1957

5 Sheets-Sheet 1

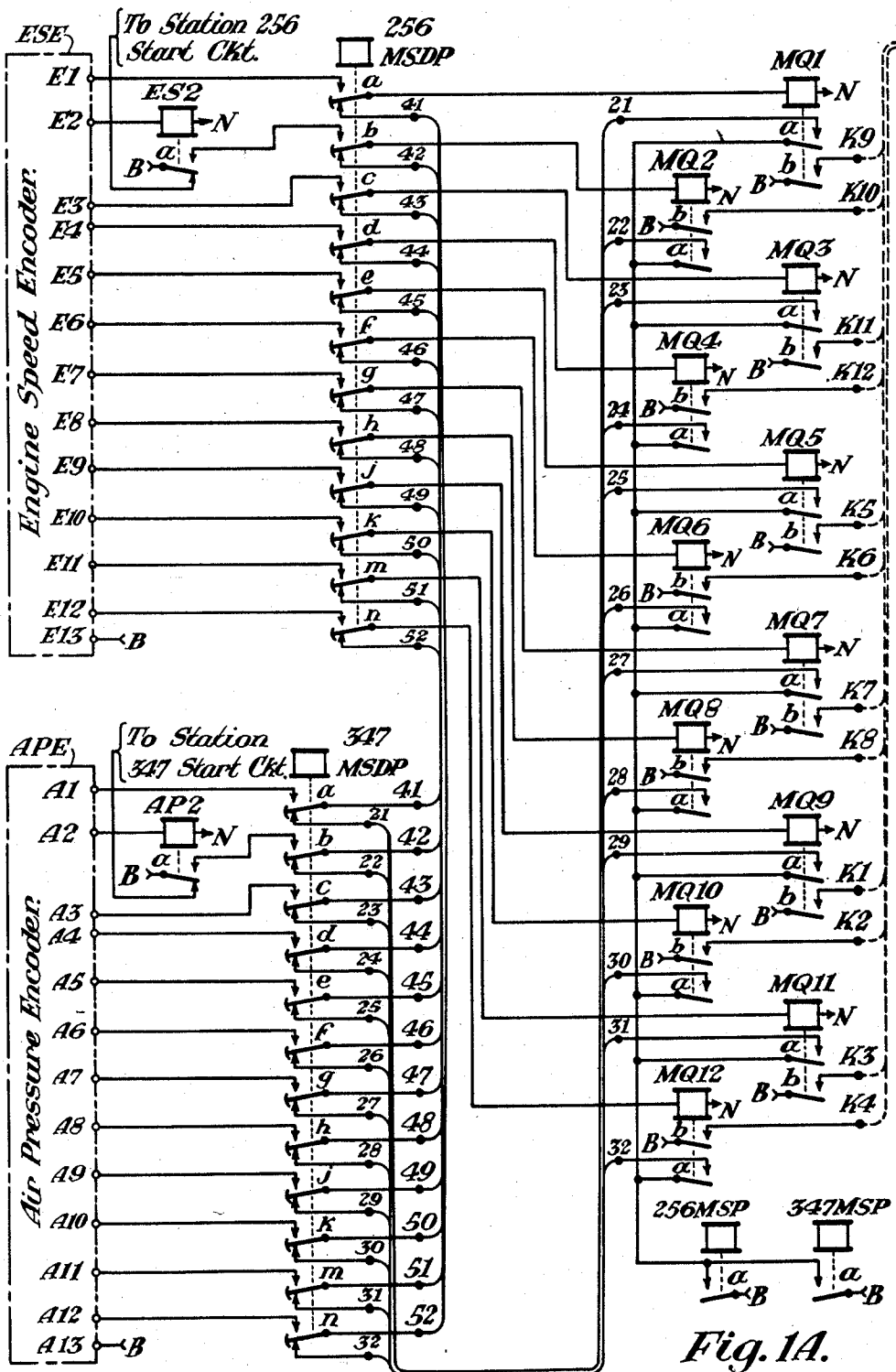


Fig. 1A.

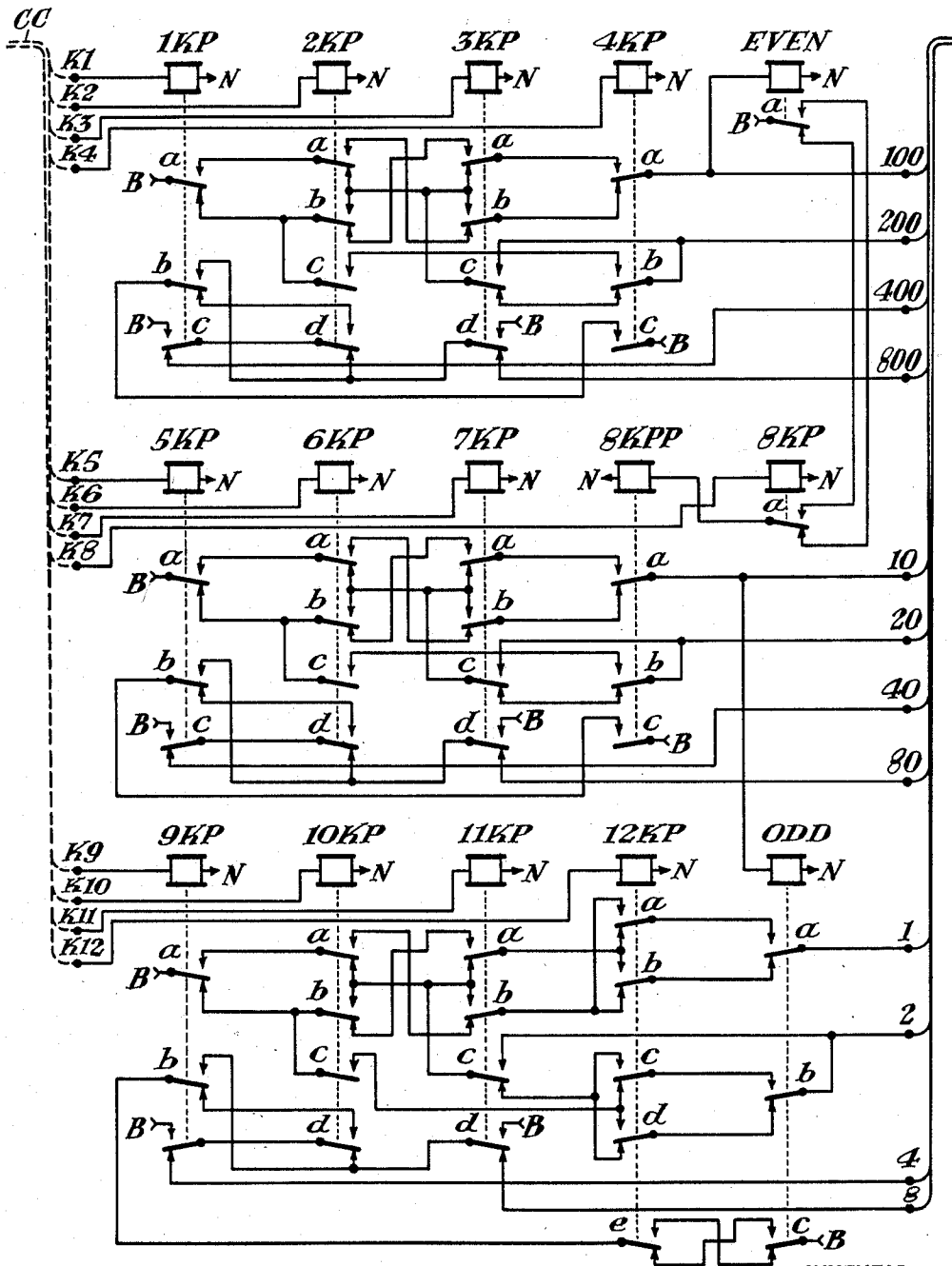
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5 Sheets-Sheet 2



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Arthur P. Jackel.

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HIS ATTORNEY

Fig. 1B.

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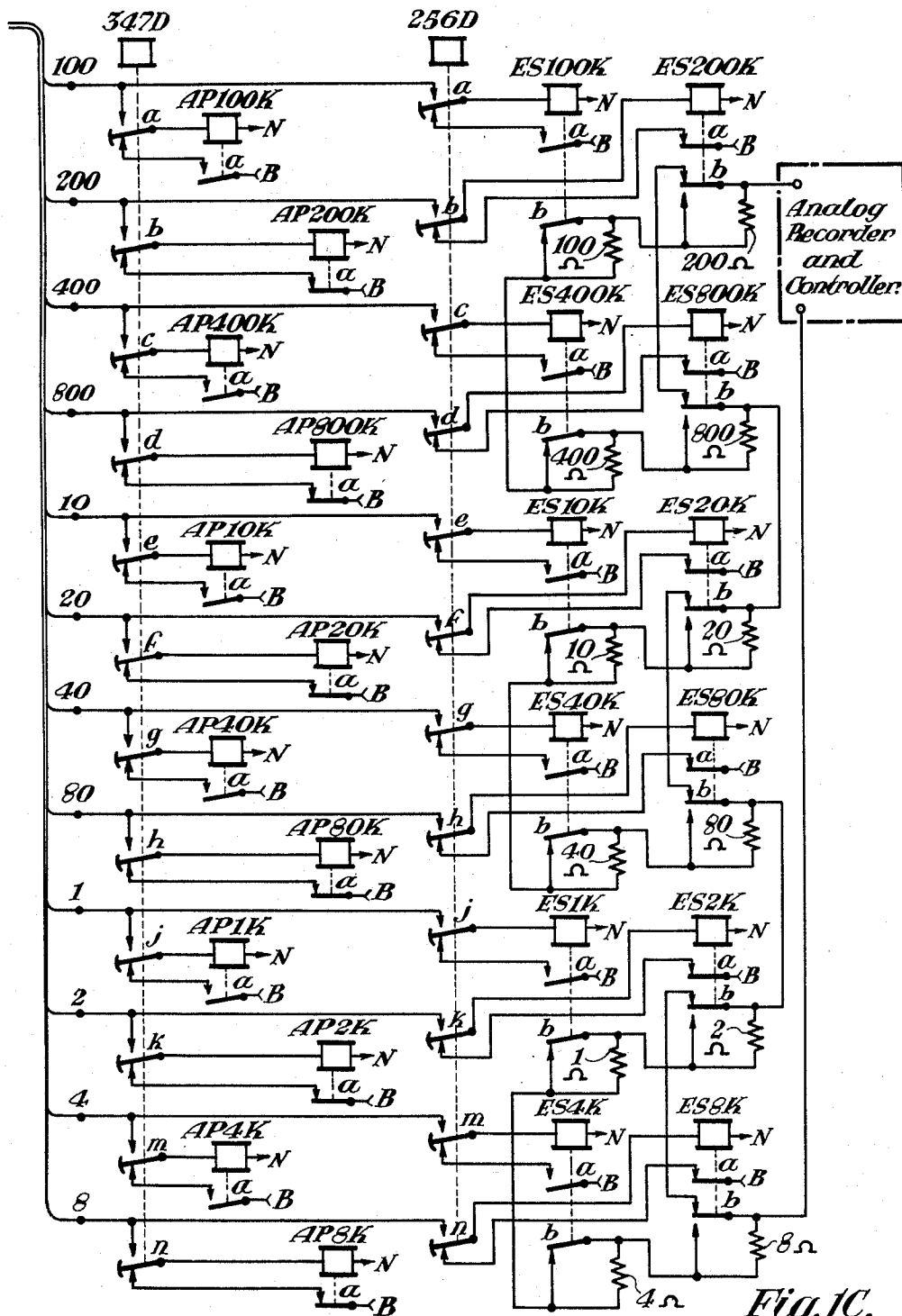
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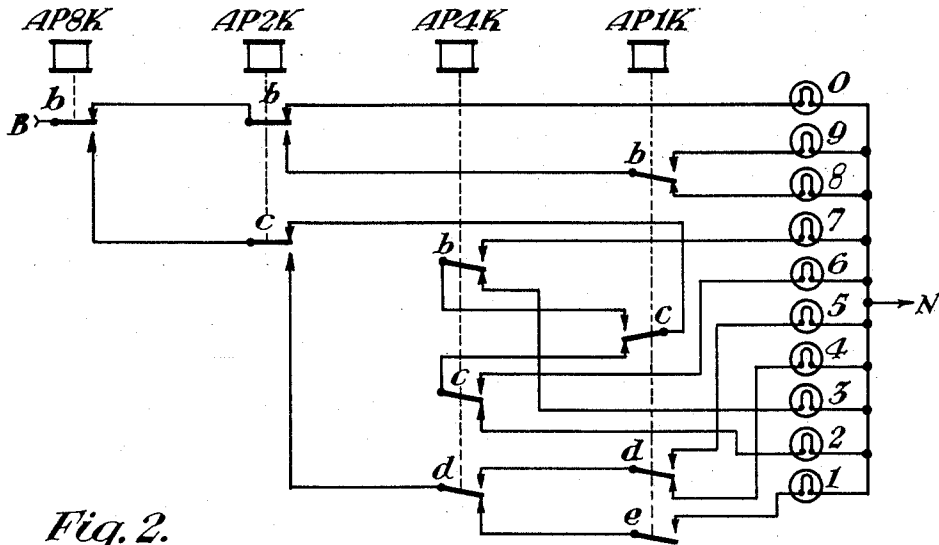


Fig. 2.

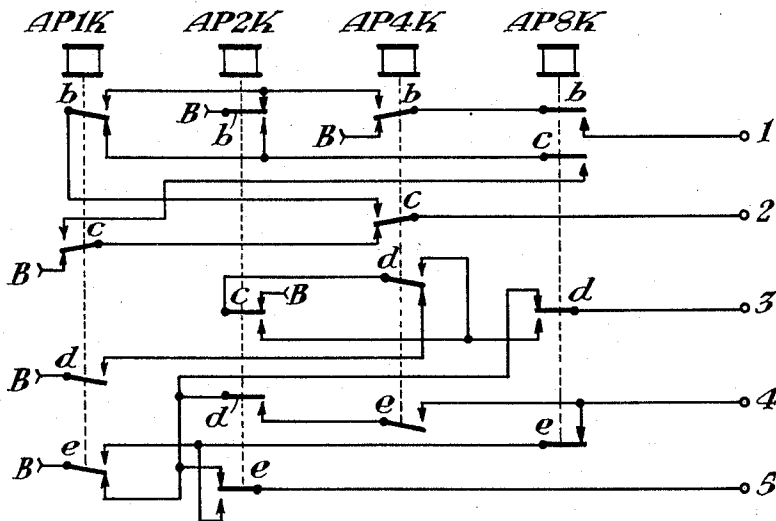


Fig. 3.

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<i>Arabic Number</i>	<i>Cyclic Binary Units</i>	<i>Code Tens.</i>	<i>Digits Hundreds</i>
000	X000	X000	X000
001	XX00	X000	X000
002	0X00	X000	X000
003	0XX0	X000	X000
004	00X0	X000	X000
005	00XX	X000	X000
006	0XXX	X000	X000
007	0X0X	X000	X000
008	XX0X	X000	X000
009	X00X	X000	X000
010	X00X	XX00	X000
011	XX0X	XX00	X000
012	0X0X	XX00	X000
013	0XXX	XX00	X000
014	00XX	XX00	X000
015	00X0	XX00	X000
016	0XX0	XX00	X000
017	0X00	XX00	X000
018	XX00	XX00	X000
019	X000	XX00	X000
020	X000	0X00	X000
051	XX0X	00XX	X000
063	0XX0	0XXX	X000
099	X000	X00X	X000
100	X000	X00X	XX00
116	0XX0	XX0X	XX00
148	XX0X	00XX	XX00
216	0XX0	XX00	0X00
248	XX0X	00X0	0X00
333	0XXX	0XXX	0XX0
433	0XXX	0XX0	00X0
999	X000	X000	X00X

Fig. 4.

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CODE CONVERTERS

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4 Claims. (Cl. 340—347)

My invention relates to a code converter for translating one form of binary code into a second form. More particularly, my invention relates to a code converter by which indications from remote stations received at a central office in cyclic binary decimal form are converted into a decimal binary form which may be weighted for readout and control purposes.

It is well known in control systems for oil or gas pipelines to transmit indications from the remote locations to a central office in code form. These indications include information concerning such items as pipeline or other pressures, engine or pump speeds, flow rates, etc. Items of this nature are encoded to simplify the transmission of the information over the remote control system. It is necessary, of course, that the code form be appropriate for the type of control system in use. For some types of remote control system, more than one form of code may be applicable to represent the indications to be transmitted. However, of the various types of codes, the binary type is most convenient for transmission over the well-known time code remote control system. Of the various binary codes, the form known as the cyclic or reflected binary code is particularly well adapted as it eliminates all possible errors, and the resulting ambiguity, in the readings.

However, the cyclic form of binary code, since the numerical representation is partially complementary, is not easily adapted for readout or recording through analog converters. It has been found more useful if such codes may be converted or translated into a more conventional binary form in which the numerical representations may be weighted, so that translations to digital or analog form are simplified. In other words, the cyclic binary code form is very convenient for transmission when the time code type of remote control system is used. It is difficult, however, to provide a simple readout format into the various forms, that is, digital or analog, desired for recording and control purposes. The readout into the desired form is much simplified if conversion is first made to a weighted binary code which lends itself readily to translation for either digital or analog recording.

It is therefore an object of my invention to provide a code converter which will convert from a cyclic binary decimal code into a weighted decimal binary code.

Another object of my invention is to provide a code converter at a central location to translate indications received from a remote station in a cyclic binary form into a decimal binary form.

Still another object of my invention is to provide an indication system which will transmit information to a central point from several remote locations in a code form convenient to the communication system or channel in use, and to convert the received indications into a form readily translatable into digital or analog form for readout purposes.

Another object of my invention is to provide a code conversion system at a central office which will receive

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coded information from several remote locations and convert the information into another code form more readily useable at the central location.

A further object of my invention is to provide a single code translation matrix at a central location by which indication codes of a cyclic binary form received from several remote locations may be converted into a conventional binary form whose digits may be weighted to simplify readout procedure.

Other objects and features of my invention will become apparent as the specification progresses.

Referring now to the drawings, Figs. 1A, 1B, and 1C, when taken in the order named from left to right, provide a diagrammatic showing of an indication system, including a recording device, which embodies one form of the code converter of my invention.

Fig. 2 is a diagrammatic showing of another circuit arrangement for a second form of recording device or visual display apparatus which may be used in place of the similar apparatus shown in Fig. 1C.

The circuit arrangement of Fig. 3 is a diagrammatic showing of a third form of recording apparatus which may replace that shown in Fig. 1C and is particularly adapted for readout into an electric typewriter or teletype circuit.

Fig. 4 is a chart of one form of cyclic binary code as used herein to describe the general features of my invention.

In each of the drawings, similar reference characters refer to similar parts of the apparatus.

In practicing my invention, each item or type of information that is to be measured or indicated at a central office is established as a separate station in the indication system. The actual numerical information or indication is first encoded in a cyclic binary decimal code form, which will be described in more detail hereinafter. In other words, each station in the remote indication system comprises only one type or item of information so that several stations may exist at one remote location in order to provide indications at the central office of all of the information from that point. Of course, in the type of code system contemplated, as will be described hereinafter, only one code, that is, one type of information, is transmitted at a time. Each information bit or digit of the binary code is transmitted on a separate code step and received in the office by a separate receiving relay. As is customary with any binary code, each receiving relay needs only to be energized or deenergized to indicate the two possible values of the code digits, that is, the numeral 1 or the numeral 0. Each receiving relay at the office serves to receive in turn the same information bit or code digit from each indicating device at the several field locations.

The system as illustrated transmits numerical information having three digits in its arabic form. These three digits become twelve information bits or digits in the cyclic binary code, thus requiring twelve receiving relays at the office. A matrix of the receiving relay contacts is provided to convert the received code form, that is, the cyclic binary decimal code, into a more conventional binary code in which the digits are relatively weighted on the scale 8-4-2-1. In the contact matrix used, the contacts of the first four receiving relays are used to convert the hundreds digits into the new form of code. At this point, I add a first additional or sensing relay to the translation system in order to determine the relationship of the digits in the tens group. This determination is necessary for reasons which will be described later when the code form is more fully discussed. Contacts of the second four receiving relays are used to convert the tens digits of the code. Contacts of the first additional relay enter into this second circuit arrangement to determine

whether the received code indicates a true or a complementary number. Also as a part of this translation matrix for the tens digit, I add a second additional relay to sense the relationship, in accordance with the particular tens digit being converted, of the following unit digits. Contacts of the last four receiving relays and of the second additional relay are then used to form a contact matrix which converts the received code digits representing the units into the second code form, the contacts of the second additional relay differentiating between true and complementary numbers.

Each of these circuit arrangements in the translation matrix places energy selectively on four output leads in accordance with the received code for that particular digit. In other words, the converted code also comprises twelve digits or information bits that are divided into groups of four to represent the arabic numerals comprising the hundreds, the tens, and the unit digits of the original information. The energy on these output leads is evaluated in terms of the previously mentioned 8-4-2-1 weight factor. This evaluation, however, is actually accomplished after the indication storage relays are energized, each output lead controlling one of the storage relays. A set of twelve such relays is thus required for each field station from which information is being received. The final information readout from the storage relays is by digital or analog translation into the desired form in order to be recorded or displayed by visual indicators, teletypes, analog converters, electric typewriters, etc., as may be desired in the system.

Before describing the circuit arrangements and the general system of my invention, it will be well to describe briefly the forms of binary code used herein. At each of the field stations, the output of the encoders is a cyclic or reflected binary code, also known as the "Gray" type code. The cyclic or reflected system of binary numbers is an arrangement of the number order to follow a definite pattern characterized by the change of only one digit between any number and either number adjacent to it. The code form is adaptable to rearrangement into several variants or secondary forms so that this type of binary code may be fitted to the particular job that it is desired to accomplish. However, this system of numbers is not amenable to ordinary arithmetical processes, such as addition, multiplication, etc. For these reasons, the process of decoding the characters of the reflected binary code requires in general a circuit arrangement of somewhat greater complexity than is required for decoding the characters of the more conventional binary code. This difficulty results in the fact that the elements or digits of the reflected or cyclic binary code cannot be said to have the same simple significance to each other as do the code elements of the more conventional binary code. In contrast, the more conventional type binary code is easily decoded since the code elements or digits may be weighed arithmetically, particularly in the well-known weighted form 8-4-2-1. However, as previously mentioned, because of its principal characteristic, that is, that only one code bit changes between adjacent numbers, which eliminates any ambiguity in the code, the cyclic code is particularly well adapted to transmission by the time code type of remote control and indication systems.

The specific variant of the cyclic or reflected binary code shown herein is of the Giannini Datex code type, as developed by the Datex division, G. M. Giannini & Co., Inc. However, it is to be understood that the principles of my invention are not limited to this specific variant or secondary form of the cyclic code and that other forms may be used with only slight modifications of the circuit arrangements. The Datex code, as used herein, representing a three-digit arabic number, consists of twelve code or information bits. In practice, the Datex encoder translates an arabic decimal number from the

information apparatus, in this application a three-digit number, into a cyclic decimal number which it then encodes into a binary code. The final output is a cyclic binary decimal code having twelve digits which are divided into groups of four to represent the original three digits of the arabic numeral. Referring now to Fig. 4, it is to be seen that the arabic numbers shown in the left-hand column, consisting of three digits each, are represented by the twelve-digit binary code shown in the three right-hand columns entitled, from left to right, respectively, "Units," "Tens," and "Hundreds."

Each group of four digits of the binary code is actually a separate cyclic code representing the actual arabic numeral which occurs in the corresponding digital place in the original number. As shown in Fig. 4, an energized code bit is represented by an X and a deenergized code bit by an 0. As will appear hereinafter, when describing the circuits, the terms energized and deenergized may be taken to mean whether or not, respectively, energy appears upon the numbered output terminals of the encoder (Fig. 1A) as they correspond, from top to bottom, with the code digits shown in Fig. 4 from left to right. Referring first to the units column, it is to be seen that for the numerals 0 to 9, the binary code varies only one digit at a time. Considering the arabic numbers 0 to 9 (shown as 000 to 009), the tens digit, being zero, remains in the code combination X000. Throughout the same range of arabic numbers, the hundreds digit, which also is zero, likewise remains in the combination X000. It is also to be noted that between the arabic numbers 010 and 019, the tens digit, being one, is represented by the code group XX00, which is the same combination shown for the numeral 1 in the second line of the unit column. Referring further to the arabic number 116 wherein the hundreds digit is one, this hundreds digit is represented by the similar code group XX00. Other examples illustrate that the tens digits change, that is, below the number 100, to correspond with the units digits shown from 0 to 9, and likewise the hundreds digits, as shown in Fig. 4, continue to vary, as they increase, in a corresponding manner.

Because of the change in the code group for the tens digit between the numbers 009 and 010 (from X000 to XX00), the code group representing the unit digit remains the same in these two arabic numbers so as not to exceed the one code bit change between adjacent numbers which characterizes this form of binary codes. In other words, the code group representing the unit digit 0 in the arabic number 010 is the same as the code group representing the unit digit 9 in the preceding number. From a study of the units column in Fig. 4, it is also apparent that the code groups representing the units digits from 010 to 019 change in the reverse order to that of the corresponding units digit in the first ten numbers. In other words, the various four bit code combinations vary in one direction for ten changes and then vary in the opposite direction for the next ten changes. This cycle reoccurs every twenty changes in each of the digit columns. In other words, the code group representing the unit digit 0 is the same for the number 020 as it is for the number 000. Likewise, the code group representing the tens digit in the number 100 is the same as the code group representing the tens digit 9 in the numbers from 090 to 099. However, the code group representing the tens digit in 216, for example, is the same as the code group representing the tens digit in 016. As long as only a three-digit arabic number is being represented by the binary code, the progression of the code groups representing the hundreds digit is only in the one direction. A reversal in the direction in which the hundreds digit code group changes would only occur above the number 1000.

It becomes apparent, therefore, that the four bit combination for any digit may represent either the true number or a complementary number, i.e., the result if the

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actual numeral is subtracted from 9. From a study of the code groups shown in Fig. 4, it is apparent that when the hundreds digits are even, that is, the arabic numeral is even, the representation of the tens digit in the code is a true number, whereas when the arabic digit for the hundreds is odd, the code group representing the tens digit is complementary. Likewise, when the tens digits are even, the unit code group represents a true number, whereas when the tens digits are odd, the unit code group represents a complementary number. Therefore, the need can be realized for conversion to only the true numbers at the receiving end of the information from the field stations. This fact enters into the conversion circuit arrangement, as will appear later. It may be briefly said, however, that a determination must be made, when converting from the cyclic binary code to a more conventional binary code form, whether a particular code group, that is, the four bit combination, represents an actual numeral equal to, above, or below the numeral 5, in the scale 0 to 9. This determination is applied directly for the units digit. However, it will be understood that when the tens digit is being considered, the numeral 5 represents an actual value of 50. In other words, it must be determined whether the original arabic number was equal to, above, or below 50, in the range 00 to 99, with no regard being given to the actual value of the hundreds digit but only to whether it is an odd or an even numeral.

Referring now to Fig. 1A, there are shown two field stations from which information is to be recorded at the central office shown in Figs. 1B and 1C. Both stations in Fig. 1A are shown at the same remote location. However, as will appear as the specification progresses, the two stations need not necessarily be so located nor is my system limited to only two field stations, as the information from a plurality of stations may be transmitted to and recorded at the central office. These stations may be located each at a separate place or grouped with several stations being located at a fewer number of separate places. The stations are connected to the central office by a communication system which must provide at least twelve channels, one for each bit or digit of the cyclic binary code, as previously described. The communication system may be a direct-wire type, that is, it may have an individual wire between the office and each of the remote locations for each code bit. The more economical form, however, of one of the well-known remote control and indication systems. This remote control and indication system may be of the time code type, such as shown and described in Letters Patent of the United States No. 2,411,375, granted to me on November 19, 1946, for a Remote Control System, or as shown and described in Letters Patent of the United States No. 2,698,425, granted December 28, 1954, to A. B. Miller, also for a Remote Control System. It is to be understood, of course, that this present indication system is not limited to the remote control system shown in either of these two cited references. For purposes of the following description, however, the use of a system such as shown therein will be considered, but only such specific details of the system as are necessary to understand my invention have been shown in order to simplify the drawings. The general system is represented conventionally by the cable CC which extends between the remote location and the office, that is, between Fig. 1A and Fig. 1B, and is illustrated as having twelve indication channels designated by the reference characters K1 to K12, inclusive.

It is to be noted that the apparatus at each location in Figs. 1A, 1B, 1C, and also in Figs. 2 and 3, is provided with a source of direct current, such as a battery of suitable size and power. However, for the sake of simplicity, these batteries are not illustrated, their positive and negative terminals being indicated by the reference characters B and N, respectively. Also, certain

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of the relay contacts shown are of the continuity transfer type, that is, when the relay is energized, the front contacts close a short time before the corresponding back contacts open, and when the relay releases, a reverse action occurs. Such contacts are so designated, in the usually accepted manner, by a short arc which is appended to the contact armature.

In order to provide a differentiation between the stations of Fig. 1A, one has been assigned the station call code 256 while the other is assigned station call code 347, such station calls being usual in the remote control system herein being considered. Each station is further provided with an encoder of the Giannini Datex type previously described. Each encoder has twelve output terminals corresponding in order to the twelve code bits or digits. In other words, terminals 1 to 4, inclusive, correspond to the four code bits representing the unit digit; terminals 5 to 8, inclusive, correspond to the tens digit, while terminals 9 to 12, inclusive, correspond to the hundreds digit. A thirteenth terminal is shown as connected to terminal B of the local source, from which energy is supplied through internal circuits of the encoders, which are not shown for simplicity, in a combination according to the three-digit arabic number being encoded. Station 256 thus is provided with the engine speed encoder ESE having output terminals E1 to E12, inclusive. Station 347 is likewise provided with an air pressure encoder APE having output terminals A1 to A12, inclusive.

Each remote location is provided with one set of twelve readout relays, such as relays MQ1 to MQ12, inclusive. Only one set of such relays is required for the several stations which may be placed at the one remote location. Thus only one set of relays MQ1 to MQ12 is shown for stations 256 and 347 which have hereinbefore been described as being at the same location. It is to be understood that if stations 256 and 347 were placed at separated locations, a set of readout relays MQ would be required for each station. However, since there is no change in the principle of operation whether there be one set or several sets of such readout relays, it is sufficient to show both stations at the same location with the single set of readout relays.

Each relay MQ is energized from one or the other of the two encoders, depending upon which station at this location is active at a particular time, as determined by the master and station detecting repeater relays 256MSDP and 347MSDP. For example, one circuit for relay MQ1 may be traced from terminal E1 of encoder ESE over front contact *a* of relay 256MSDP through the winding of relay MQ1 to terminal N. It is obvious that if energy is applied to terminal E1 from terminal B, relay MQ1 will be energized and will pick up when front contact *a* of relay 256MSDP is closed. A second circuit for energizing relay MQ1 may be traced from terminal A1 of encoder APE over front contact *a* of relay 347MSDP, wire 41, back contact *a* of relay 256MSDP, and the winding of relay MQ1 to terminal N. Energy is applied to terminal A1 from terminal B of the local source connected to terminal A13 through circuits within encoder APE in accordance with the information being encoded. Similar energizing circuits for the remaining relays MQ, with the exception of relay MQ2, may be traced and include terminals E3 to E12 of encoder ESE and terminals A3 to A12 of encoder APE and other contacts of the two relays MSDP. The energizing circuits for relay MQ2 will be described shortly.

Each master and station detecting repeater relay is energized for a short period during the initial or station selection part of an indication code being transmitted from the corresponding station and then releases for the remainder of the indication code. These relays are not energized when the corresponding station is receiving a control code from the central office. Thus it is obvious that the energizing circuits for the relays MQ are com-

pleted for only a short time during the initial part of an indication code, and the relays are thus energized or remain deenergized in accordance with the binary code output of the encoder of the then active station.

Each of the MQ relays is provided with a stick circuit which is effective to hold the relay energized during the remainder of an indication code. The stick circuit for relay MQ1, for example, may be traced from terminal B over front contacts *a*, in multiple, of the master and station repeater relays 256MSP and 347MSP, front contact *a* of relay MQ1, wire 21, back contact *a* of relay 347MSDP, wire 41, back contact *a* of relay 256MSDP, and the winding of relay MQ1 to terminal N. The master and station repeater relay of a station is energized, only during an indication code from that station, when the last step of the station code call is transmitted. This occurs prior to the release of the associated relay MSDP. The MSP relay then remains energized throughout the remaining portion of that indication code so that its front contacts remain closed until the final or reset code step at the end of the code. It is thus apparent that the stick circuit for any relay MQ, once established by the closing of its own front contact *a* and the associated back contact of the active relay MSDP, remains closed until the indication code is completed. It is to be noted that the transfer contacts of the MSDP relays are all of the continuity transfer type so that no interruption of the energization of any relay MQ occurs during the transfer from the pickup circuit to the stick circuit for that relay.

Each station is also provided with a code change relay, such as relay ES2 and relay AP2. These relays are used to sense a change in the information being encoded in the corresponding station encoder so that an indication code may be initiated at the proper times to transmit the new information or indication to the central office. As shown in the drawings, each code change relay is connected directly to the No. 2 terminal of the corresponding encoder. For example, relay ES2 is connected directly to terminal E2 of encoder ESE, and thus is directly energized or deenergized as terminal B is or is not connected to terminal E2 through the internal circuits of the encoder which is constantly active to encode information supplied. A connection is made from terminal B over back contact *a* of relay ES2 to the starting circuits for station 256 so that, as relay ES2 picks up to open back contact *a* or releases to close back contact *a*, the start circuit for this station is actuated in the well-known manner, as described in either of the two previously mentioned patents for similar type code systems. Reference is made to these patents for a full description, it being sufficient to here understand that the application of energy to, or the removal of energy from, this circuit will initiate an indication code. Terminal E2 of the encoder is chosen to control relay ES2 since the second digit of the cyclic binary code here produced has the most frequent changes between an energized condition and a deenergized condition, as may be confirmed by reference to the code chart on Fig. 4. It is apparent from the chart that a maximum change of only three digits in the corresponding arabic number can occur before a change occurs in the energized condition of this terminal.

The form of control for the code change relays shown in the drawings provides the most frequent indication of variations of the measured information. However, depending upon the desired sensing scale, that is, the amount of change before a new indication is transmitted, the code change relays may be connected to terminals 1, 2, 3, or 4 of the encoders. In any one system, the code change relays for one item of information at the various locations may be connected to one such terminal while the corresponding relays for another item of information may be controlled over another of these terminals. It is to be understood that the present showing is not intended to limit the control of these relays to the connection to

terminal 2, but that only the principle of operation is illustrated.

The first energizing circuit for relay MQ2 is completed from terminal B over front contact *a* of relay ES2 and front contact *b* of relay 256MSDP. A second energizing circuit for relay MQ2 is completed over front contact *a* of the corresponding code change relay AP2 for station 347 and front contact *b* of relay 347MSDP, wire 42, and back contact *b* of relay 256MSDP. The stick circuit for relay MQ2 is similar to the stick circuit previously traced for relay MQ1, and is likewise similar to the stick circuits for the other MQ relays. It is to be noted that the starting circuit for station 347 is controlled by back contact *a* of relay AP2 in a manner similar to that already discussed for station 256.

The office is provided with twelve receiving relays 1KP to 12KP, inclusive, as shown in Fig. 1B. These receiving relays are energized in accordance with the positions of the MQ relays associated with the station transmitting the indication code then being received. However, there is not a direct relationship between the corresponding numbers. This results from the fact that, for purposes of code conversion, it is more convenient to receive first at the office the four bit code combination representing the hundreds digit, so that the code conversion of this code combination may occur first. The reasons for this will be more readily apparent as the description of the conversion circuits is amplified. The energizing circuits for the KP relays, as shown in a conventional manner, are completed through the twelve indication channels of the code system represented by cable CC. For example, the energizing circuit for relay 1KP may be traced from terminal B over front contact *b* of relay MQ9, channel K1 in the code system, and the winding of relay 1KP to terminal N. Circuits for the remaining KP relays may be similarly traced over the code channels bearing the numbers corresponding to the KP relays. These relays are not provided with stick circuits but are held up after they are energized until the code ends and are then released. The energized combination of the KP relays occurring during any indication code is in accordance with the raw Datex binary code established by the encoder at the station transmitting at that particular time. Since only one indication code at a time may be transmitted over this type of a code system, only one indication, i.e., the information from a single station, is received at any one time at the office.

These KP relays with their contacts form the principal part of the translation matrix by which the raw Datex code, that is, the cyclic binary code received, is converted into a weighted conventional binary code also including a similar number of information or code bits. This code conversion occurs simultaneously with the receipt of the code from the particular station then active. The converted information or code is stored in indication relays at the office, there being a group of twelve such relays for each station in the system. For example, in Fig. 1C, station 347 is provided with twelve indication storage relays such as relay AP100K. The numerical portion of the reference character for each of these indication relays K is in accordance with the weight value given to the code bit stored by that particular relay. These relays are divided into groups of four to store the corresponding code bits for the hundreds, the tens, and the unit digits of the converted code. The energizing circuits for these relays are completed when delivery relay 347D picks up to close its front contacts. Relay 347D is energized and picked up during the final step of the indication code to complete these circuits and releases immediately thereafter. For example, the circuit for relay AP100K may be traced, as will be explained later, through the translation matrix in Fig. 1B, to wire 100, and thence over front contact *a* of relay 347D through the winding of relay AP100K to terminal N. It is obvious that if energy is applied to wire 100,

relay AP100K will then be energized. Upon the release of delivery relay 347D, a stick circuit is completed from terminal B over front contact *a* of relay AP100K, back contact *a* of relay 347D, and the winding of relay AP100K to terminal N. It is to be noted that the transfer contacts of relay 347D, and the corresponding relay 256D for the other station, are all of the continuity transfer type so that no interruption in the energization of an indication relay occurs upon the transfer from its energizing circuit to its stick circuit.

Station 256 is also provided with a group of twelve indication storage relays at the office, these relays appearing in the right-hand portion of Fig. 1C, illustrated for example by relay ES100K. The indication relays ES-K are energized over front contacts of delivery relay 256D, and those relays which may be energized during a particular indication code are then held energized over stick circuits which include back contacts of this delivery relay. This operation is identical with that previously described for station 347 and its indication relays.

Selection circuits over contacts of these indication storage relays can then be provided to operate different types of recording devices. For example, in Fig. 1C, there is shown for station 256 an analog resistance control for operating a voltage sensitive chart recorder or a servo operated controller. Other types of recording devices are shown in Figs. 2 and 3 where they are illustrated as being associated with station 347. These devices will be more fully explained hereinafter as the description progresses.

I shall now describe the transmission, conversion, storage, and recording of a particular indication. Assume first that the engine speed which is indicated by station 256 rises so as to change to the value 116. It is immaterial to the present description whether this numerical value 116 represents the true speed in revolutions per minute, or whether it is merely a relative indication of the true speed of the corresponding engine, as long as the necessary adjustments are accomplished at both the station and the office to cause this new number to indicate the equivalent speed. In any event, the change in the rising speed to the indication 116, which is encoded by encoder ESE into a Datex binary code, causes energy to be now applied to terminal E2 of the encoder. The resulting energization and pickup of relay ES2 actuates the starting circuits of station 256 so that an indication code is initiated and is transmitted by the code system to the office.

During the transmission of this code, relay 256MSDP picks up in a manner previously discussed. The closing of front contacts of relay 256MSDP completes circuits for energizing MQ relays 2, 3, 5, 6, 8, 9, and 10. The circuit for relay MQ2, of course, is completed over front contact *a* of relay ES2, which was picked up by energy on terminal E2, and front contact *b* of relay 256MSDP. Reference to the code chart of Fig. 4 indicates that energy also appears on terminals E3, E5, E6, E8, E9, and E10 when the arabic number 116 is encoded. When relay 256MSDP releases, the stick circuits for the energized MQ relays are completed in the manner previously described, relay 256MSP having been energized previous to the release of relay 256MSDP so that its front contact *a* is now closed. At the proper time in the indication code, the energized station MQ relays send long code steps to the office energizing the associated KP relays. In the present code, KP relays 1, 2, 5, 6, 8, 10, and 11 are energized by energy on the corresponding channels K. For example, relay 1KP is energized over the circuit which includes front contact *b* of relay MQ9, channel K1, and the winding of relay 1KP. The energizing circuit for relay 10KP may be traced from terminal B over front contact *b* of relay MQ2, channel K10, and the winding of relay 10KP to terminal N. The energizing circuits for the other KP relays energized at this time are similar and may be

determined by an inspection of the drawings taken in connection with the preceding description.

The KP relays pick up progressively throughout the indication code. However, the indication storage relays K pick up only at the end of the indication code when the delivery relay is energized. In the present example, when relay 256D picks up, circuits are completed for the K relays to be energized in accordance with the received code as converted by the matrix established by the contacts of the KP relays. For example, a circuit is completed for relay ES100K, which may be traced from terminal B over front contact *a* of relay 1KP, front contact *a* of relay 2KP, back contact *b* of relay 3KP, back contact *a* of relay 4KP, wire 100, front contact *a* of relay 256D, and the winding of relay ES100K to terminal N. In the present example, this is the only hundreds indication relay energized as the circuits for supplying energy to wires 200, 400, and 800 are interrupted at some point in the contact matrix by an open front or back contact of the KP relays. It is thus apparent that the contact matrix formed by contacts of relays 1KP to 4KP, inclusive, has converted the cyclic code combination received, that is, the four-digit code group, into a conventional four-digit binary code in which the output is weighted to give relative values, that is, the wire 100 has been energized so that relay ES100K has picked up.

At this time, the first additional relay provided at the office, the sensing relay Even is also energized in parallel with relay ES100K. It is obvious that relay Even is energized at any time that energy appears on wire 100 since the relay winding is connected directly to this wire lead. The reference character designating this relay is chosen to indicate that this relay is energized at any time that an even number of the KP relays preceding it in the relay matrix are energized. In other words, relay Even is energized when an even number of the relays 1KP to 4KP, inclusive, are energized. In the present example, two of these relays, 1KP and 2KP, are energized.

Considering now the conversion of the code combination representing the tens digit, it will be apparent that only relay ES10K should be energized. It will also be noted that contacts of the repeater relay 8KPP replace contacts of relay 8KP in the conversion matrix. This repeater relay may be energized by either one of the two circuits traced from terminal B, over either front contact *a* of relay Even and back contact *a* of relay 8KP, or back contact *a* of relay Even and front contact *a* of relay 8KP, through the winding of relay 8KPP to terminal N. In the present translation, with both relays Even and 8KP energized, both energizing circuits are interrupted and relay 8KPP remains released. A similar situation would occur if both relays Even and 8KP were released. The circuit for relay ES10K is traced from terminal B over front contact *a* of relay 5KP, front contact *a* of relay 6KP, back contact *b* of relay 7KP, back contact *a* of relay 8KPP, wire 10, front contact *e* of relay 256D, and the winding of relay ES10K to terminal N. When relay 256D releases, the closing of its back contact *e* completes the stick circuit for relay ES10K which also includes front contact *a* of the latter relay.

It is to be noted that, if the contact matrix for converting the second group of four code bits into the conventional binary code included contacts of relay 8KP in the position corresponding to the contacts of relay 4KP in the hundreds translation matrix, energy would be supplied only to relay ES80K. This circuit would extend from terminal B at front contact *c* of relay 8KP (assuming relay 8KP not replaced by relay 8KPP), over front contact *b* of relay 5KP, back contact *d* of relay 7KP, wire 80, front contact *h* of relay 256D, and the winding of relay ES80K to terminal N. The previously traced circuit for relay ES10K would be open at back contact *a* of relay 8KP. It is thus apparent that relay Even determines whether the code bit combination for the tens digit is actually representing a true number or

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a complementary number. In the present example, since the hundreds digit is odd and thus the code combinations for the tens digit are varying in the reverse order, the code combination for the tens digit represents a complementary number and a reversal of the code conversion is necessary so that the weight 10 rather than the weight 80 is selected for the conventional binary code resulting from the conversion. The necessity for relay Even will be further developed hereinafter.

Since energy is applied to wire 10 in the previously described conversion of the code combination for the tens digit, the second additional relay, the sensing relay Odd, is also energized since it is connected directly to wire 10. The designation of this relay is intended to indicate that it is energized when an odd number of the preceding KP relays, that is, relays 1KP to 8KP, inclusive, are energized. In the present example, relay Odd is energized since five of these preceding KP relays, 1, 2, 5, 6, and 8, are energized.

In the translation matrix for converting the code combination representing the unit digit from the cyclic binary code into a conventional binary code, the circuitry has been somewhat modified over the arrangement shown for the tens digit. Contacts of relay Odd are included in this matrix directly and contacts of relay 12KP, the last relay in the group, are also used rather than contacts of a repeater similar to relay 8KPP. Either arrangement is satisfactory and results in the same conversion. The choice lies between using an extra relay, such as relay 8KPP, or using extra contacts on the existing relays 12KP and Odd.

The conversion of the received cyclic binary code representing the unit digit into the weighted code results in the energization of relays ES2K and ES4K. The circuit for relay ES2K may be traced from terminal B over back contact *a* of relay 9KP, front contact *b* of relay 10KP, front contact *c* of relay 11KP, wire 2, front contact *k* of relay 256D, and the winding of relay ES2K to terminal N. A second circuit also is completed which includes back contact *a* of relay 9KP, front contact *c* of relay 10KP, back contact *c* of relay 12KP, and front contact *b* of relay Odd to wire 2, and thence as previously traced to the winding of relay ES2K. The energizing circuit for relay ES4K is traced from terminal B at front contact *c* of relay Odd over back contact *e* of relay 12KP, back contact *b* of relay 9KP, front contact *d* of relay 10KP, back contact *c* of relay 9KP, wire 4, front contact *m* of relay 256D, and the winding of relay ES4K to terminal N. Each of the indication storage relays is held energized by its stick circuit completed over the back contacts *k* and *m* of relay 256D when this relay releases.

The closing of front contacts of relay Odd reverses the result of the code conversion in the matrix from the apparent numeral 3 to the numeral 6 in the weighted output. A circuit for placing energy on wire 1 could be traced, assuming relay Odd not used and contacts of relay 12KP wired similar to those shown for relay 4KP, from terminal B over back contact *a* of relay 9KP, front contact *b* of relay 10KP, front contact *b* of relay 11KP, back contact *a* (assumed) *b* of relay 12KP, and thence to wire 1. This circuit, of course, is here interrupted by the open back contact *a* of relay Odd. Under the assumed condition, the previously traced energy supply to wire 4 would originate at front contact *c* of relay 12KP, keeping in mind as an example the existing contact matrix for the hundreds digit. The circuit would then be interrupted at this open front contact of relay 12KP. Since the original circuit traced to wire 2 did not include contacts of either relay 12KP or relay Odd, energy would still be present in this wire so that the total result would have a weight of 3 rather than 6. Thus the use of the sensing relay Odd determines whether the code combination for the unit digit is representing a true or a complementary number in accordance with whether the

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tens digit is even or odd. Allowance is made accordingly in the conversion matrix for this difference.

It is thus apparent that the twelve code bits received in the cyclic binary code form as registered in the KP relays have been converted through the translation matrix including KP relay contacts into a more conventional binary code, also comprising twelve code bits. These twelve bits of the conventional code are weighted to give a relative result which may be further translated into an arabic number. The converted code is stored at the office in the indication storage relays which are held energized in a combination according to the last code received. This information may be used to indicate or control the station devices as desired.

The information stored in relays ES-K is translated, as shown in Fig. 1C, into an analog recording or control through the previously mentioned analog resistance circuit. Under normal conditions, that is, with no information stored in this bank of relays, a zero reading is entered into the recorder by holding energized the relays which represent the numerals 2 and 8 in each of the three places in the three-digit number, the present system providing for a positive reading for the number 000, in fact, for any numeral 0, in order to avoid a false indication in the event of a power failure. Under inactive conditions, therefore, a circuit may be traced from the upper terminal of the analog recorder and controller, shown conventionally by the dot-dash rectangle, over front contacts *b*, in series, of relays ES200K, ES800K, ES29K, ES80K, ES2K, and ES8K to the lower terminal of the analog recorder and controller. When the energized combination of the storage relays is that which was just previously described as a result of the indication 116 being received from station 256, the resistance control circuit may be traced from the upper terminal of the recorder and controller over back contact *b* of relay ES200K, a 100 ohm resistor whose normal shunt is now open at back contact *b* of relay ES100K, back contacts *b*, in series, of relays ES400K, ES800K, and ES29K, a 10 ohm resistor whose normal shunt is now open at back contact *b* of relay ES10K, back contacts *b*, in series, of relays ES40K and ES80K, a 2 ohm resistor whose direct shunt is open at back contact *b* of relay ES2K, back contact *b* of relay ES1K, a 4 ohm resistor whose normal shunt is open at back contact *b* of relay ES4K, and back contact *b* of relay ES8K to the lower terminal of the recorder and controller. This resistance circuit is thus weighted in order to cause the chart recorder and/or servo operated controller to set itself accordingly to record the reading 116 from the engine speed recorder at station 256, and to cause the transmission of such automatic controls as necessary to vary the engine speed to a set position. Such recording and control systems are well known and will not be further amplified in the present description.

I shall now assume that a rise in the air pressure occurs at station 347 to a relative reading 051 which is encoded by encoder APE. From a study of the code chart in Fig. 4 it will be apparent that energy is now applied to terminal A2 of this encoder, energizing relay AP2 which picks up to open its back contact *a* and thereby actuate the start circuit for station 347. The indication code is initiated and at the proper time relay 347MSDP is energized and picks up, closing its front contacts to complete energizing circuits for MQ relays 1, 2, 4, 7, 8, and 9, the source of the energy for this action being apparent from a study of the code chart of Fig. 4. When relay 347MSDP releases as the code progresses, the previously discussed stick circuits for these energized MQ relays are completed, the stick circuits all including front contact *a* of relay 347MSP, which is closed at this time. The further progress of the indication code and its transmission to the office results in the energization of KP relays 1, 7, 8, 9, 10, and 12, which pick up progressively during the progress of the indication code.

When relay 347D picks up, circuits are completed through the translation matrix for the hundreds digit to energize relays AP200K and AP800K to provide a positively weighted reading for the zero in the hundreds position. The circuit for relay AP200K is traced from terminal B over front contact *a* of relay 1KP, back contact *a* of relay 2KP, back contact *c* of relay 3KP, back contact *b* of relay 4KP, wire 200, front contact *b* of relay 347D, and the winding of relay AP200K to terminal N. The circuit for relay AP800K includes front contact *c* of relay 1KP, back contacts *d* of relays 2KP and 3KP, wire 800, and front contact *d* of relay 347D. Since there is no energy on wire 100, relay Even is not energized at this time.

With relay Even remaining released and relay 8KP picked up, one of the previously traced circuits is completed for energizing relay 8KPP which picks up to close its front contacts. Circuits are now completed for energizing relays AP10K and AP40K. The circuit for the first of these relays extends from terminal B over back contact *a* of relay 5KP, back contact *b* of relay 6KP, front contact *a* of relay 7KP, front contact *a* of relay 8KPP, wire 10, and front contact *e* of relay 347D through the winding of relay AP10K to terminal N. Energy is placed on wire 40, to energize relay AP40K over front contact *g* of relay 347D, by a circuit including front contact *d* of relay 7KP, back contact *d* of relay 6KP, and back contact *c* of relay 5KP. Since energy is present on wire 10, relay Odd is also energized and picks up at this time.

Although the cyclic code combination representing the units digit as received appears to indicate a numeral 8, the energized condition of relay Odd indicates that the code combination represents a complementary number and the translation matrix is modified so that energy is present only on wire 1, the circuit for wire 8 being interrupted at back contact *c* of relay Odd. The circuit for wire 1 extends then from terminal B over front contact *a* of relay 9KP, front contact *a* of relay 10KP, back contact *b* of relay 11KP, and front contacts *a*, in series, of relays 12KP and Odd, and from wire 1 over front contact *j* of relay 347D through the winding of relay AP1K to terminal N. When relay 347D releases at the end of the indication code, the closing of its back contacts completes stick circuits for the already energized indication storage relays so that they are retained energized.

As another example, it is assumed that the relative air pressure reading is 248, having fallen to this relative level from some higher level so as to initiate the transmission of an indication code by energizing relay AP2. From Fig. 4, it is obvious that MQ relays 1, 2, 4, 7, and 10 will be energized so that, at the office, KP relays 2, 7, 9, 10, and 12 are energized upon receipt of the indication code. With only relay 2KP energized in the first group, a circuit is completed, which includes back contact *a* of relay 1KP, front contact *b* of relay 2KP, back contact *c* of relay 3KP, back contact *b* of relay 4KP, wire 200, and front contact *b* of relay 347D, to energize relay AP200K. In this example, only this relay in the hundreds digit group is energized and relay Even likewise remains released.

With only relay 7KP energized in the second group a circuit is completed for energizing only relay AP40K. It is to be noted that with relay Even and 8KP both released, relay 8KPP likewise remains deenergized. The single circuit completed may be traced from terminal B over front contact *d* of relay 7KP, back contact *d* of relay 6KP, back contact *c* of relay 5KP, wire 40, front contact *g* of relay 347D, and the winding of relay AP40K to terminal N. With no energy on wire 10, relay Odd remains deenergized and released. In the units group, the only circuit completed includes back contact *c* of relay Odd, front contact *e* of relay 12KP, front contact *b* of relay 9KP, and back contact *d* of relay 11KP, and thence over wire 8 and front contact *n* of relay 347D to relay AP8K. As a result of the code conversion, relays

AP200K, AP40K, and AP8K are energized and remain energized at the completion of the code when their stick circuits are completed over back contacts *b*, *g*, and *n*, respectively, of relay 347D. It is to be noted in this last example that since the hundreds and the tens digits were both even numbers, both relays Even and Odd remained released so that each of the four-bit code groups were translated as representing true numbers.

I shall now discuss two other specific types of readout circuits which may be used in place of the circuit shown in Fig. 1C in connection with station 256. Referring to Fig. 2, there is shown a circuit for lighting a visual or lamp display which represents one numerical digit having a value between 0 and 9. This same circuit may be used for operating a single wire, solenoid type electric typewriter if the lamps shown are each replaced by a solenoid. It is to be noted that, in all of these readout circuits, the numeral 0 is given a positive indication by assigning to it a weighted value of 8 plus 2. In Fig. 2, the four relays shown are the same as the indication storage relays of Fig. 1C, associated with station 347, for the storage of the converted code for the unit digit. Thus the operation or control of these relays has already been discussed.

Assuming that there is stored in this relay group the conventional binary code combination representing the unit digit 8, such as has been discussed in the last preceding example above, relay AP8K only is energized. The readout circuit for lighting lamp 8 in order to indicate this unit digit may then be traced from terminal B over front contact *b* of relay AP8K, back contact *b* of relay AP2K, back contact *b* of relay AP1K, and lamp unit 8 to terminal N. Thus the weighted code combination stored in the storage indication relays is read out to provide a visual indication of the numeral 8 as part of the original information, from the field station, having a value of 248. If the storage relays shown in Fig. 2 are assumed to be storing the code combination for the hundreds digit of this same indication, so that only relay AP2K is energized, a circuit for energizing lamp unit 2 may be traced from terminal B over back contact *b* of relay AP8K, front contact *c* of relay AP2K, back contact *c* of relay AP1K, back contact *c* of relay AP4K, and lamp unit 2 to terminal N. A similar circuit could be traced for the digit 4 which is stored in the tens digit group of relays. It is apparent, therefore, that a readout circuit as shown in Fig. 2 would be required for each of the three digits comprising the information originating at the field station 347, that is, in the present example, the number 248. Proper coordination between the three circuit arrangements for the readout of the three figures would be required if the circuit is used for the operation of a single wire, solenoid type electric typewriter. However, such circuits and control are well known and are not shown in Fig. 2.

Referring now to Fig. 3, there is shown a five-wire circuit for reading out one numerical digit having a value between 0 and 9 to control a five-wire electric typewriter, for direct Teletype transmission, or into tape punching apparatus. Again, the four relays shown are the indication storage relays from Fig. 1C associated with station 347 which store the code combination indicating the unit digit of the received information. Assuming again that there is stored in these relays the converted code combination representing the unit digit 8, circuits are completed for energizing terminals 2 and 3 at the right-hand side of the figure. The five terminals shown lead through the control circuits for the five-wire electric typewriter or into the Teletype transmission circuits. These details are not shown as they are well known and are unnecessary for an understanding of the apparatus and circuit arrangements of my invention. The circuit for energizing terminal 3 may be traced from terminal B at back contact *e* of relay AP1K over front contact *d* of relay AP8K to terminal 3. A second circuit is traced from terminal

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B over back contacts *c* of relays AP1K and AP4K to terminal 2, terminals 2 and 3 being the only two terminals supplied with energy for the digit 8.

It is to be noted that, under the normal conditions shown, relays AP2K and AP8K are energized to store the numeral 0 which is then read out into the recording apparatus. The same circuit over back contacts *c* of relays AP1K and AP4K exists for energizing terminal 2. Likewise, the circuit previously traced for terminal 3 is also completed. In addition, a circuit is completed for supplying energy to terminal 5, which circuit may be traced from terminal B over back contact *e* of relay AP1K and front contact *e* of relay AP2K to terminal 5.

If, as was previously discussed, the number 051 has been transmitted from station 347 to the office so that, in the unit storage relays shown, relay AP1K is energized, circuits are completed for energizing terminals 1, 2, 3, and 5. The first of these circuits may be traced from terminal B over back contacts *b* of relays AP4K and AP8K to terminal 1. Terminal 2 receives energy from the local source over the circuit including back contact *b* of relay AP2K, back contact *c* of relay AP8K, front contact *c* of relay AP1K, and back contact *c* of relay AP4K. The circuit for terminal 3 is traced from terminal B at front contact *d* of relay AP1K, over back contact *d* of relay AP4K, back contact *c* of relay AP2K, and back contact *d* of relay AP8K to terminal 3. A circuit extending from terminal B over front contact *e* of relay AP1K and back contact *e* of AP2K places energy on terminal 5. Circuits for other numbers between 0 and 9 may be traced as desired but it is felt to be unnecessary to further describe this circuit arrangement herein. It is to be noted that similar arrangements would be required for the indication storage relay groups for the hundreds and tens digits with the necessary coordination controls to provide a proper sequence of readout into the electric typewriter or teletype transmission circuits.

The circuit arrangement and apparatus of my invention described in the preceding paragraphs thus provide a code converter by which a cyclic binary decimal code received at an office from any one of a plurality of stations may be converted through a single translation matrix into a decimal binary code. Weighted values may then be given to the various code digits of the latter form to allow for simple and effective readout in either digital or analog form. The use of a cyclic binary decimal code for transmitting information from the stations avoids ambiguity since, of the twelve code bits representing the three digit number, only one code bit changes for each successive number change. In addition, the minimum number of code steps in the remote code system are required to transmit such a cyclic code in its original state from the field station to the office. It was shown that only twelve code steps were required for a three-digit number. This is a distinct advantage in reducing the time necessary for the transmission of a particular indication. When several stations are located at a single field installation, only one set of readout relays is required for the several encoders to provide character to all the indication codes from that location. Also, at the office, only one set of receiving relays and one converting or translating matrix is required for all of the stations to convert the cyclic binary code into the weighted binary code. The preceding two factors are a distinct advantage in reducing the amount of apparatus necessary for the overall indication system and for simplifying the circuit arrangements required. It has already been mentioned that, from the final storage relays in which is stored the weighted decimal binary code, output or readout circuits can be provided in either digital or analog form, so that the various types of information received from the several stations may be recorded in the most applicable manner and form desired.

Although I have herein shown and described but one form of code converter embodying the arrangement of my

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invention, it is to be understood that various modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described by invention, what I claim is:

1. An indication system to transmit information from a plurality of remote stations to a central recording office comprising, encoding means at each station to encode the information into a cyclic binary code form having a selected plurality of code digits, said cyclic code form changing in accordance a fixed operating cycle, a communication system having at least one channel for each code digit and including transmitting means associated with each station to transmit the cyclic codes over said systems to said office, a single group of receiving relays at said office including one relay to receive each cyclic code digit, said relays being energized in selected combinations according to the combination of code digits received; a single code conversion circuit arrangement at said office including contacts of said receiving relays, a plurality of output leads, and a sensing relay means; said conversion circuit arrangement being selectively responsive to each energized combination of said receiving relays to translate the corresponding received cyclic code into an arithmetic binary code form and to energize said output leads in a selected combination in accordance with the translated code form, said sensing relay means being responsive to the energized combination of said receiving relays to determine the position of the corresponding cyclic code in said operating cycle and to modify the response of said conversion circuit in accordance with that position so that the resulting translated code form represents a true number, and a storage means responsive to the transmission of a code from a particular station and to the energized combination of said output leads to store separately in said arithmetic binary form the information from that particular station.

2. A code converter system to translate coded three digit numerical information from a cyclic binary form into a weighted decimal binary form comprising: a given number of receiving relays to receive the coded information in said cyclic binary code form, said relays being divided into a first, a second, and a third group to represent a first, a second, and a third digit respectively of said three digit information, each relay group being energized in a selected cyclic combination according to the particular digital information received, each cyclic combination according to its position in the code cycle representing the true value or the complementary value of the corresponding digit; a given number of output wires energized in selected combinations to transmit said particular information in said weighted binary code form, said output wires being divided into a first, a second, and a third group representing said first, second, and third digits respectively; a code translation matrix formed of contacts of said receiving relays and including a first and a second sensing relay, said matrix having a first circuit arrangement including contacts of said first relay group, said first circuit arrangement being effective to energize said first group of output wires in a weighted code combination corresponding to the first digit as represented by the energized cyclic combination of said first relay group, said first circuit arrangement being further effective to energize said first sensing relay if an even number of said first group of relays is energized, said matrix having a second circuit arrangement including contacts of said second relay group and of said first sensing relay, said second circuit arrangement being effective to energize said second output wire group in a weighted code combination corresponding to the second digit as represented by the energized cyclic combination of said second relay group, said first sensing relay contacts modifying the energized combination of

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said second wire group to represent only the true value of said second digit according as said first sensing relay is energized or deenergized, said second circuit being further effective to energize said second sensing relay if an odd number of all of said receiving relays of said first and said second relay groups is energized; said matrix further having a third circuit arrangement including contacts of said third relay group and of said second sensing relay, said third circuit being effective to energize said third output wire group in a weighted code combination corresponding to said third digit as represented by the energized combination of said third relay group, said second sensing relay contacts modifying the energized combination of said third wire group to represent only the true value of said third digit according as said second sensing relay is energized or deenergized.

3. A code converter system to translate three digit numerical information encoded in a cyclic binary form into a weighted decimal binary form comprising: a given number of receiving relays to receive the coded information in said cyclic binary code form, said relays being divided into a first, a second, and a third group to represent a first, a second, and a third digit respectively of said three digit information, each relay group being energized in a selected cyclic combination according to the particular digital information received, said second and said third digital combinations representing a true number of a first or a second level according as the true value of the preceding digit is an even or an odd number; a given number of output wires energized in selected combinations to transmit said particular information in said weighted binary code form, said output wires being divided into a first, a second, and a third group representing said first, second, and third digits respectively; a code translation matrix formed of contacts of said receiving relays and including a first and a second sensing relay, said matrix having a first circuit arrangement including contacts of said first relay group, said first circuit arrangement being effective to energize said first group of output wires in a weighted code combination corresponding to the first digit as represented by the energized cyclic combination of said first relay group, said first circuit arrangement being further effective to energize said first sensing relay if the true value of the first digit is an odd number, said matrix having a second circuit arrangement including contacts of said second relay group and of said first sensing relay, said second circuit arrangement being effective to energize said second wire group in a weighted code combination corresponding to the second digit as represented by said energized cyclic combination of said second relay group, said first sensing relay contacts determining said second digit to be of said first or said second level according

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as said first sensing relay is energized or deenergized, said second circuit being further effective to energize said second sensing relay if the true value of the second digit is an odd number; said matrix further having a third circuit arrangement including contacts of said third relay group and of said second sensing relay, said third circuit being effective to energize said third wire group in a weighted code combination corresponding to said third digit as represented by the energized combination of said third relay group, said second sensing relay contacts determining the third digit to be of said first or said second level according as said second sensing relay is energized or deenergized.

4. A code converter circuit arrangement to convert numerical indication codes from cyclic binary form into decimal binary form, said cyclic binary form comprising a plurality of code bits having a cyclic relationship, a particular cyclic code representing a true or complementary number value according to its place in the code cycle, said decimal binary form comprising a similar number of code bits having an additive relationship to designate the numerical indication carried, said circuit arrangement comprising a plurality of receiving relays one for each code bit of said cyclic code form, said receiving relays being energized in a selected cyclic combination to receive a particular indication code, a sensing relay controlled by said receiving relays and energized only when said cyclic code is within a predetermined portion of the code cycle, a translation matrix including front and back contacts of said receiving relays and said sensing relay and effective to convert an indication code from its cyclic binary form only into the equivalent decimal binary form representing the true number value of the indication, and a plurality of output leads one for each code bit of said decimal binary form having connections to said matrix to receive the code bits of the converted code.

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