

Dec. 21, 1937.

F. S. KINKEAD

2,102,719

SIGNAL DISTORTION INDICATING AND MEASURING DEVICE

Filed Aug. 4, 1934

4 Sheets-Sheet 1

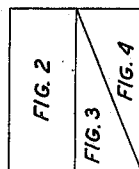
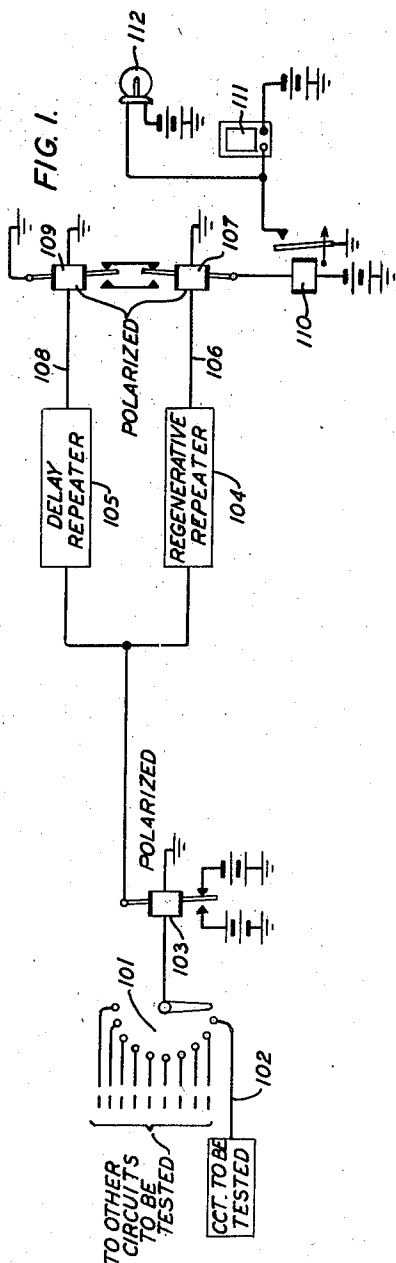


FIG. 3

FIG. 4

INVENTOR
F.S. KINKEAD
BY *J. W. Schmitt*
ATTORNEY

Dec. 21, 1937.

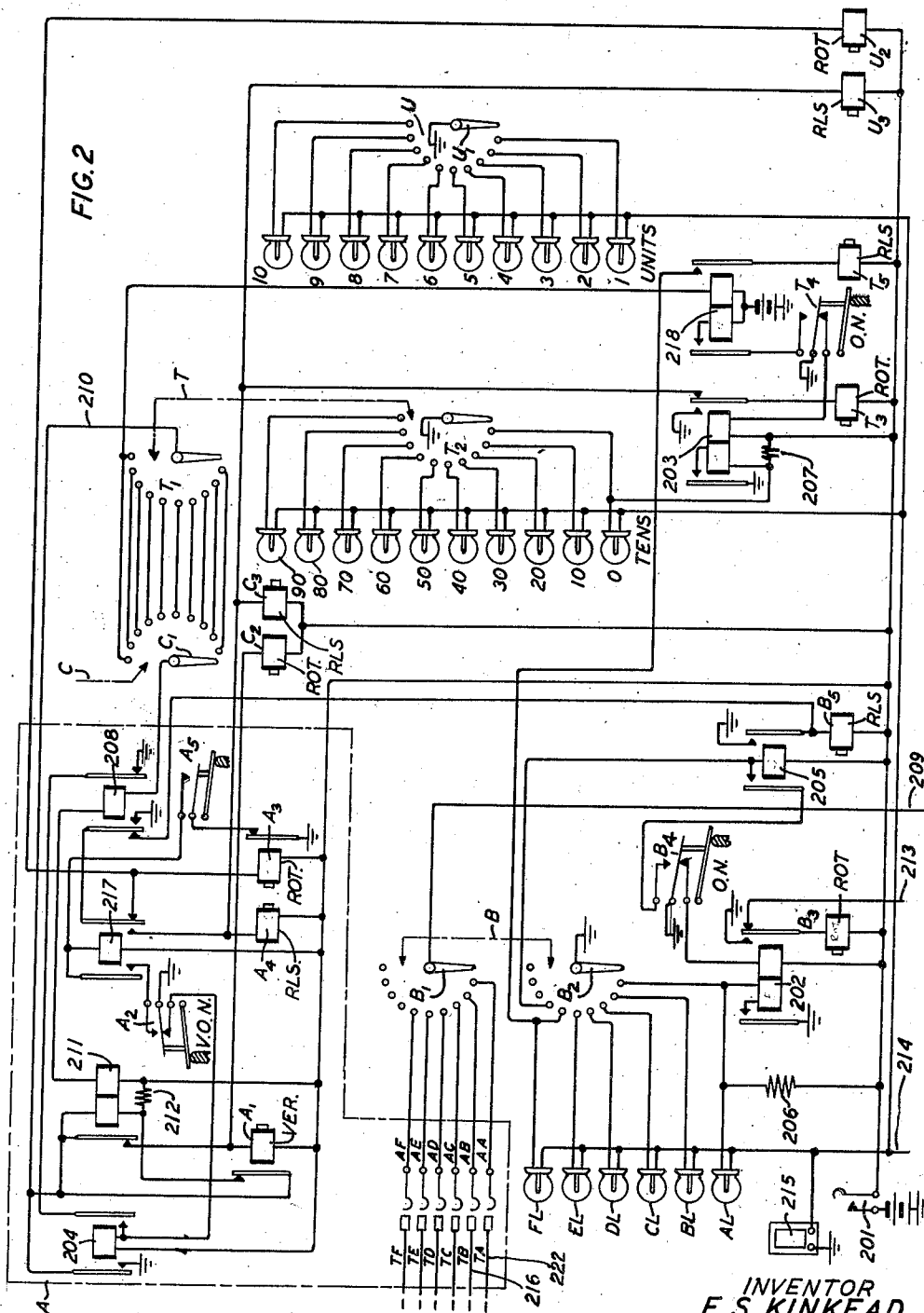
F. S. KINKEAD

2,102,719

SIGNAL DISTORTION INDICATING AND MEASURING DEVICE

Filed Aug. 4, 1934

4 Sheets-Sheet 2



INVENTOR
F. S. KINKEAD
BY *J. W. Schmiel*
ATTORNEY

Dec. 21, 1937.

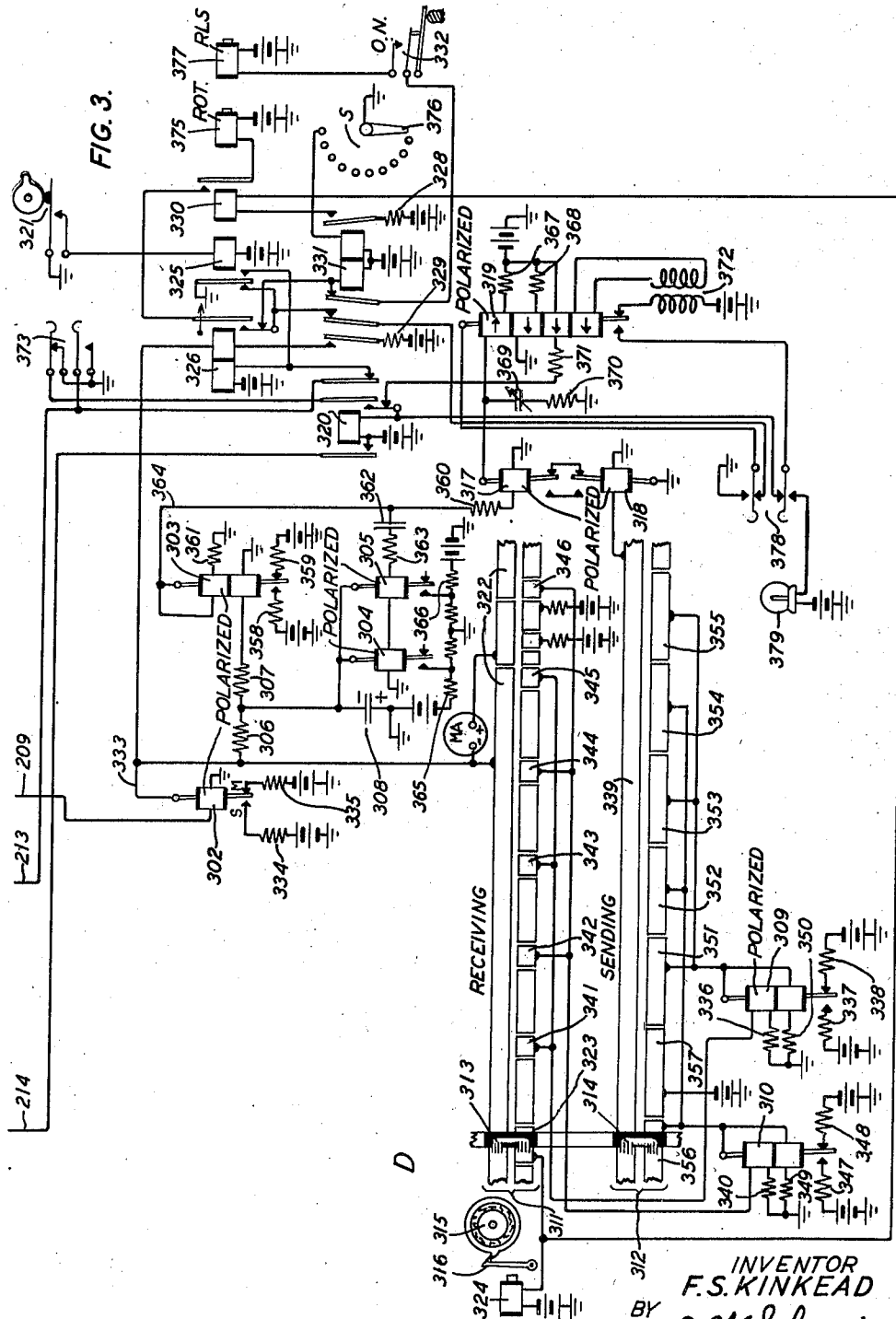
F. S. KINKEAD

2,102,719

SIGNAL DISTORTION INDICATING AND MEASURING DEVICE

Filed Aug. 4, 1934

4 Sheets-Sheet 3



INVENTOR
F.S. KINKEAD

BY

J W Schmied
ATTORNEY

ATTORNEY

Dec. 21, 1937.

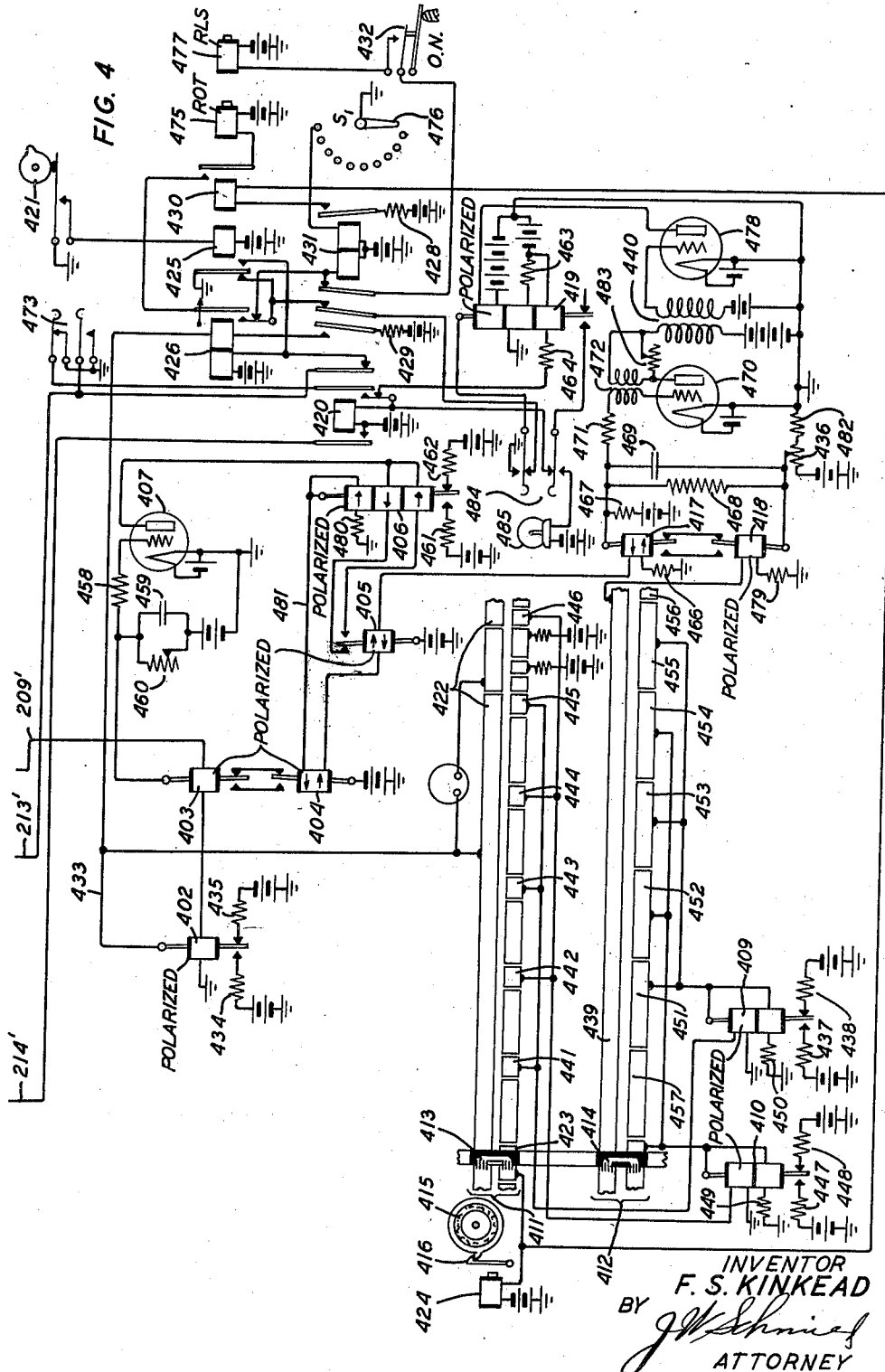
F. S. KINKEAD

2,102,719

SIGNAL DISTORTION INDICATING AND MEASURING DEVICE

Filed Aug. 4, 1934

4 Sheets-Sheet 4



UNITED STATES PATENT OFFICE

2,102,719

SIGNAL DISTORTION INDICATING AND MEASURING DEVICE

Fullerton S. Kinkead, Ridgefield Park, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 4, 1934, Serial No. 738,416

12 Claims. (Cl. 178—69)

This invention relates to impulse transmission systems and more particularly to electrical measuring systems wherein means are employed for determining the existence of distortion of received telegraph signals.

An object is to provide a circuit for instantaneously measuring the maximum distortion in signals received over a transmission line in start-stop printing telegraph systems.

In transmitting telegraph signals each made up of a plurality of impulses and each impulse having a definite length, distortion of the impulses and therefore of the signals, may be produced by various causes inherent in the line or in the apparatus connected therewith or both. The distortion with which this invention is concerned manifests itself in lengthening or shortening the duration of the impulses which constitute the signal transmitted over the line. This lengthening or shortening of the duration of the impulses interferes with the proper recording of the signals at any station connected to the line and, consequently, impairs the efficiency of transmission.

According to the present invention, the circuit measures the distortion of the received signal by comparing it with the original signal. The original signals are reproduced at the point of measurement from the received signals by means of the start-stop regenerative repeater. Inasmuch as the repeater causes the regenerated signal to lag the received signal by approximately half a signal dot length, it is necessary to introduce an equivalent delay in the received signal in order that it may be compared with the regenerated signal. The regenerated signals and the delayed received signals are impressed on a circuit which measures a difference in phase each time the line condition changes from marking to spacing or vice versa. Obviously this method of measuring distortion will fail if the distortion is so great that the regenerative repeater can no longer reproduce the original signal.

The objects and advantages of the invention will be better understood from a consideration of the following description of the operation of a system embodying this invention read in conjunction with the accompanying drawings in which:—

Fig. 1 illustrates schematically the relationship between the component circuit elements of the system and the general principle involved in the measuring of signal distortion by this invention;

Fig. 2 shows diagrammatically the selecting and indicating circuits which associate the lines under test, individually, with the repeating and signal distortion measuring circuits and which, upon encountering a line on which the signal distortion exceeds a predetermined amount, pro-

vide a visible and an audible indication thereof;

Fig. 3 shows diagrammatically a start-stop regenerative repeater, a delay repeater, and the signal distortion measuring circuit;

Fig. 4 shows an alternative arrangement of the start-stop regenerative repeater, delay repeater and distortion measuring circuit of Fig. 3; and

Fig. 5 indicates the manner in which Figs. 2, 3 and 4 should be arranged.

Referring to Fig. 1, the signal distortion measuring system herein disclosed functions in the general manner hereinafter set forth. The incoming start-stop printing telegraph transmission lines terminate on the banks of a test selector 101. Assume that the brush of selector 101, under control of circuit means which will later be described in detail, is in contact with the bank terminal to which transmission line 102 is connected. The signals incoming over line 102, each signal composed of a plurality of impulses having a definite length, are received over the bank terminal and brush of selector 101 and transmitted to ground through the winding of polarized relay 103. In response to the incoming signal impulses, relay 103 operates and releases, which in turn repeats corresponding impulses of positive and negative potential to the regenerative repeater circuit 104 and to the delay repeater circuit 105 in parallel. The regenerative repeater 104 functions, in a manner which will hereinafter be described in detail, and reproduces the original signal over conductor 106, to ground through the winding of polarized relay 107.

Since the signal distortion is measured by comparing the received signal with the regenerated signal, and since the regenerative repeater introduces a lag in the reproduced signal, it is necessary to provide an equivalent lag in the incoming signal. This is accomplished by the delay repeater circuit 105, the detailed operation of which will be set forth hereinafter. The incoming signal impulses, after being delayed, are repeated over conductor 108, to ground through the winding of polarized relay 109.

Relay 110 is normally operated in a circuit from grounded battery, through its winding, over the armatures and the right contacts of relays 107 and 109 to ground. As hereinbefore stated, relay 107 operates and releases in response to the impulses of the regenerated original signals while relay 109 operates and releases in response to the impulses of the delayed received signals. If perfect signals are received over the circuit under test, in this case over transmission line 102, relays 107 and 109 operate and release in unison and the circuit through the winding of slow-release relay 110 is opened for an interval no greater

than the travel time of the armatures of relays 107 and 109. This open period is insufficient to cause the release of relay 110. If, however, distortion is present in the received signals, the operation and release of relay 109 will no longer be in synchronism with the operation and release of relay 107 with a resultant lengthening of the open interval in the operating circuit for relay 110. When the distortion in the received signal exceeds a predetermined amount, the circuit through relay 110 is opened for a period sufficient to cause this relay to release. Relay 110, in releasing, connects ground over its armature and back contact to grounded battery through signal 111 and through lamp 112. Signal 111 and lamp 112 respectively provide audible and visual indications of the distortion condition encountered on the line under test.

Having described the system in a general manner, a detailed description of the operation of the circuit elements shown on drawings Figs. 2, 3 and 4 will now be set forth.

Referring to Fig. 2, switch A is of the well known step-by-step type having in this case six brushes paired, such as brushes AA and AB, AC and AD, and AE and AF respectively, mounted on a common shaft (not shown). Each pair of brushes has access to one of three terminal banks (not shown) of switch A. Each terminal bank has 100 pairs of terminals arranged in ten levels, ten pairs of terminals per level. The first bank has ten sets or pairs of terminals TA and TB per level, the second bank ten sets or pairs of TC and TD terminals per level, and third bank ten sets or pairs of TE and TF terminals per level. Brushes AA, AB, AC, AD, AE and AF therefore each have access to one hundred selectable terminals TA, TB, TC, TD, TE and TF respectively. A vertical magnet A₁ is provided for advancing the shaft (not shown) and the brushes AA, AB, AC, AD, AE, and AF one step at a time in a vertical direction. A rotary magnet A₂ is provided for horizontally rotating the shaft and brushes one step at a time over the terminals of any vertically selected level. A release magnet A₄ provides for releasing the shaft and brushes to their normal position. Associated with the shaft and brushes of switch A are the vertical off-normal springs A₂ and the tenth rotary step springs A₅ the operation and functions of which will be described fully hereinafter.

Switches B, C, T and U are of the well known single movement rotary type having one or more terminal banks, each bank having ten individual terminals selectable by an individual brush. The switches are provided with rotary magnets B₃, C₂, T₃ and U₂ respectively, by which the brush on each switch is advanced progressively, one step at a time, over its associated bank terminals. The respective release magnets B₅, C₃, T₅ and U₃ provide for the release of the brushes of their respective switches to their normal positions. Associated with switches B and T are the off-normal springs B₄ and T₄ respectively, the function of which will be hereinafter set forth in detail.

As previously stated, the banks of switch A are composed of one hundred groups of six terminals each. Each of these groups, corresponding to terminals TA, TB, TC, TD, TE and TF, are accessible to the respective switch brushes AA, AB, AC, AD, AE and AF. Connected to each of the aforementioned six hundred terminals is a multiple branch of a start-stop printing telegraph transmission line on which signal distortion measurements may be made.

To start the distortion measurements, key 201 is operated, thereby connecting grounded battery to the right-hand windings of relays 202 and 203, windings of relays 204 and 205, windings of rotary magnets A₃, B₃, C₂, T₃ and U₂, windings of release magnets A₄, B₅, C₃, T₅ and U₃, to the left winding of relay 202 through resistance 206, and the left winding of relay 203, through resistance 207. Relay 202 operates through its right-hand winding to ground over the normally closed contacts of the off-normal spring B₄ and locks through its left-hand winding from ground on its left armature and front contact to grounded battery through resistance 206. Relay 203 operates through its right winding to ground over the normally closed contacts of the off-normal springs T₄ and locks through its left winding from ground over its left contact and armature to battery through resistance 207. Relay 204 operates from the battery over the contacts of key 201, through its winding, to ground over the normally closed contacts of the off-normal springs A₂ and locks over its contact and right-hand armature to ground over the right armature and contact of relay 208.

Relay 202, in operating, energizes rotary magnet B₃ in a circuit from ground over the right front contact and armature of relay 202, through magnet B₃, to battery over the contacts of key 201. Magnet B₃, energized, causes the B switch brushes B₁ and B₂ to advance one step and contact the first terminal of their respective banks. The off-normal springs B₄ operate during the first step of switch B and remain in the operated position until the switch is restored to normal. In operating, springs B₂ transfer the ground over their armature from the right winding of relay 202 to the left armature of relay 205. Relay 202 remains operated since it is locked through its left winding. With the B₁ brush on the first terminal of its associated bank a circuit is completed from the AA brush of switch A, over the bank terminal and brush B₁, to conductor 209. With the B₂ brush on the first terminal of its associated bank, ground over the B₂ brush is connected to the AL lamp, resistance 206, and the left winding of relay 202. This ground short-circuits the left winding of relay 202 which releases.

Relay 203, operating and locking over previously traced circuits, energizes rotary magnet T₃ from ground over its right front contact and armature, winding of magnet T₃, to battery at key 201. In energizing, magnet T₃ causes brushes T₁ and T₂ to advance one step to contact the first terminals of their respective banks. During this first step of switch T the off-normal springs T₄ operate, transferring the ground on their armature from the right winding of relay 203 to the left armature of relay 218. The T₁ brush connects conductor 210 to its first associated bank terminal, and the T₂ brush connects ground, over the first terminal of its associated bank, to lamp O, resistance 207 and the left winding of relay 203. This ground short-circuits the left winding of relay 203 which releases.

Relay 204, operating and locking over previously traced circuits, connects ground over its left front contact and armature, over conductor 210, brush T₁ and first terminal of associated bank, to the first terminal of the bank associated with brush C₁. The same ground over the left front contact of relay 204 is also connected to the left winding of relay 211 and also to the armature and back contact of relay 211, through the

windings of vertical magnet A₁ and rotary magnet C₂ to battery at key 201. Vertical magnet A₁, in energizing, causes the AA, AB, AC, AD, AE and AF brushes of switch A to advance one vertical step, bringing these brushes into position at the first horizontal rows or levels of TA, TB, TC, TD, TE and TF terminals, respectively, of the A switch banks. The vertical off-normal springs A₂ operate upon the first vertical step of switch A and, in operating, open the operating ground for relay 204 and connect ground to the left front contact of relay 217. Relay 204 does not release at this time since it is locked to ground over the right armature of relay 208. The C₂ magnet, in energizing causes the C₁ brush to advance one rotary step and contact the first terminal of its associated bank. The operation of magnet A₁, in addition to causing a vertical step of the brushes of switch A, also opens the circuit extending from ground over the left contact and armature of relay 204, armature and back contact of magnet A₁, resistance 212, to battery at key 201 thereby removing the short circuit from the left winding of relay 211. Relay 211 operates from ground over the left armature of relay 204, left winding of relay 211, resistance 212, to battery at key 201. In operating, relay 211 opens the circuit to the windings of magnets A₁ and C₂ causing these magnets to de-energize and release. Magnet A₁, in releasing again closes the previously traced short circuit on the left winding of relay 211. Relay 211 does not release at this time since, when brush C₁ contacted its first associated bank terminal, a circuit was established from battery at key 201, through the right winding of relay 211 and the winding of relay 208, brush C₁ and first bank terminal, first bank terminal and brush T₁, to ground over the left armature and front contact of relay 204. This circuit holds relay 211 and causes relay 208 to operate. Relay 208, in operating, closes a circuit from ground on its left front contact and armature, over the right armature and back contact of relay 217, through the windings of rotary magnets A₃ and U₂, to battery at key 201. Magnet A₃, in energizing, causes brushes AA, AB, AC, AD, AE and AF to make one rotary or horizontal step and contact the first set of TA, TB, TC, TD, TE and TF terminals of the A switch banks. Magnet U₂, in energizing, causes brush U₁ of switch U to make one rotary step and contact the first terminal of its associated bank thereby connecting ground to the units lamp 1. Relay 208, in operating, also opens the locking circuit for relay 204. Relay 204 releases and opens the circuit from ground over its left front contact and armature, brushes T₁ and C₁, winding of relay 208 and right winding of relay 211, thereby releasing relays 208 and 211. Relay 208, in releasing, opens the previously traced circuits through the windings of rotary magnets A₃ and U₂, and connects ground over its right back contact and armature to the right armature of relay 204. Relay 211, in releasing, again closes the circuit from the windings of vertical magnet A₁ and rotary magnet C₂ to the left armature of relay 204.

As hereinbefore set forth, switch A has now advanced one vertical and one rotary step and switches B, C, T and U have each advanced one rotary step. The brushes of switch A are in contact with the first of the one hundred groups of TA, TB, TC, TD, TE and TF terminals of the A switch banks. Brushes B₁, B₂, C₁, T₁, T₂ and U₁ are in contact with the first terminal of their

respective banks. With the switches in the above condition, the first of the six hundred start-stop printing telegraph transmission lines terminating on the bank terminals of switch A is connected to the associated repeaters and distortion measuring circuit over a path which may be traced from the first transmission line (represented by conductor 222) terminal TA, brush AA, first terminal of bank associated with brush B₁, brush B₁, and over conductor 209 to the circuits of Fig. 3 or Fig. 4 as the case may be.

Upon the connection of a transmission line over conductor 209 of Fig. 2, the delay repeater, regenerative repeater and signal distortion measuring circuits of Figs. 3 or 4 function to measure the signal distortion on that line. The detailed manner in which the circuits of Figs. 3 and 4 operate will be described hereinafter, their operation at this point being covered only to the extent involved in the further functioning of circuits of Fig. 2.

The signal distortion on the first transmission line is measured for a definite interval and, if the distortion does not exceed a predetermined amount, the measuring circuit functions at the end of the measuring interval and returns a ground to conductor 213 to cause the circuit of Fig. 2 to advance to the next transmission line in a manner shortly to be set forth. Should the signal distortion on the first line exceed a predetermined amount, the distortion measuring circuit returns battery to conductor 214 of Fig. 2 and locks in that condition. Battery on conductor 214 completes circuits through the electromagnetic signal 215, through the AL lamp to ground over brush B₂, and through the tens lamp 0 and the units lamp 1 over brushes T₂ and U₁ respectively. Signal 215 gives an audible alarm and lamps AL, 0 and 1 light, indicating that excessive distortion has been encountered on the first transmission line of that group of lines terminating on the one hundred TA terminals of the A switch bank. This alarm and lamp indication continues until the operation of a releasing key 318 in the associated measuring circuit of Fig. 3 or the corresponding key 484 in Fig. 4 at which time battery is removed from conductor 214 and ground is returned to conductor 213 by the measuring circuit.

The ground which is connected to conductor 213, at the conclusion of the distortion measurement on the first line, is extended over the right back contact and armature of relay 202, through the winding of rotary magnet B₃ to battery at key 201. Magnet B₃ energizes and advances brushes B₁ and B₂ to the second terminal of their respective banks. The next transmission line (represented by conductor 216) is now connected over the first TB terminal, brush AB, second bank terminal and brush B₁, to the repeaters and distortion measuring circuit over conductor 209. The advance of brush B₂ to its second bank terminal transfers the ground over that brush from the AL lamp to the BL lamp so that, in the event of excessive signal distortion, the return of battery to conductor 214 by the measuring circuit causes audible signal 215 to operate and lamps BL, 0 and 1 to light which indicates the condition encountered on the first transmission line of that group of lines which are connected to the one hundred TB terminals of the A switch banks. At the termination of the distortion measurement ground is again connected to conductor 213 by the measuring circuit. This, and subsequent applications of ground to conductor 213 at the termination of the signal distortion measurement on

each succeeding transmission line, cause rotary magnet B₃ to energize and advance the B₁ and B₂ brushes one step at a time. Brushes B₁ and B₂ successively contact the third, fourth, fifth and sixth terminals of their respectively associated banks. The transmission lines connected to the A switch bank terminals TC, TD, TE and TF are connected over brushes AC, AD, AE and AF respectively, and over brush B₁ to the repeater and measuring circuits over conductor 209. Brush B₂, advancing simultaneously, successively connects ground to lamps CL, DL, EL and FL to prepare the circuit for lighting the particular lamp identifying each group of terminals in the event that battery is returned to conductor 214 due to excessive signal distortion on any line.

On the seventh time that ground is connected to conductor 213, magnet B₃ again energizes and advances brushes B₁ and B₂ to the seventh terminal of their banks. Ground on brush B₂ is connected over its seventh bank terminal, through the winding of relay 205 to battery at key 201, operating relay 205 which locks over its left front contact and armature to ground over the upper contact and armature of the off-normal springs B₄. Relay 205, in operating, connects ground over its right front contact and armature through the winding of the B switch release magnet B₅ to battery at key 201. This ground from relay 205 also connects, over the left back contact and armature of relay 208 and the right armature and back contact of relay 217, through the windings of rotary magnets A₃ and U₂, to battery at key 201. Rotary magnet A₃ energizes and advances the A switch brushes AA, AB, AC, AD, AE and AF one rotary step to contact the second set of TA, TB, TC, TD, TE and TF terminals. Rotary magnet U₂ energizes and advances brush U₁ one step thereby removing the ground from the units lamp 1 and connecting this ground to the units lamp 2. Release magnet B₅, in energizing as previously stated, causes brushes B₁ and B₂ to restore to normal in any well known manner, at which time the off-normal springs B₄ also restore to their unoperated or normal condition. Springs B₄, in restoring, open the locking circuit for relay 205 and again connect ground to the right winding of relay 202. Relay 205 releases, removing the ground from rotary magnets A₃ and U₂.

With ground connected to its right winding, relay 202 operates through that winding to battery over key 201. Relay 202 in operating locks through its left winding and, over its right front contact and armature, connects ground to the winding of rotary magnet B₃. Magnet B₃ energizes in a circuit to battery over key 201 and advances brushes B₁ and B₂ to their first respective bank terminals. Upon this first step of switch B the off-normal springs B₄ operate, opening the circuit through the right winding of relay 202 and connecting ground to the left armature of relay 205. Ground on brush B₂, over the first bank terminal, short-circuits the left winding of relay 202 which releases, and is also connected to lamp AL. Relay 202, in releasing, removes ground from the winding of magnet B₃ and connects this magnet winding to conductor 213.

The transmission lines terminating on the second set of TA, TB, TC, TD, TE and TF terminals are now connected over brushes AA, AB, AC, AD, AE and AF respectively to the terminals of the bank associated with brush B₁. Since brush B₁ is on its first bank terminal the line terminating on terminal TA is connected to the repeater and measuring circuits over conductor 209.

Subsequent applications of ground to conductor 213 advance switch B, thereby associating each transmission line connected to the second set of terminals on the first level of the A switch banks with the repeater and measuring circuits. When switch B reaches its seventh bank terminals relay 205 again operates and locks. Relay 205, in operating, advances the brushes of switches A and U one rotary step and releases switch B in the same manner as hereinbefore set forth. Switch B again advances under control of ground applications on conductor 213 and the lines connected with the third set of terminals on the first level of the A switch banks are associated with the measuring circuit. This action of switches A, B and U continues until switch A has taken its tenth rotary step at which time the tenth step off-normal springs A₅ operate.

With springs A₅ operated, the next release of rotary magnet A₃, after the tenth rotary step of switch A, closes a circuit from ground over the armature and back contact of magnet A₃, over the operated contacts of springs A₅, through the winding of relay 217, to battery at key 201. Relay 217 operates and locks over its left armature to ground over the operated springs A₂. When relay 205 now operates upon the subsequent seventh step of switch B, a circuit is closed from ground over the right contacts of relay 205, through release magnet B₅, and over the left back contact and armature of relay 208, right armature and front contact of relay 217 to battery through the windings of release magnets A₄, C₃ and U₃, and also over the right back contact and armature of relay 203 to battery through the winding of rotary magnet T₃. Magnet T₃ energizes and advances brushes T₁ and T₂ to the second terminal of their respective banks. Magnets A₄, C₃ and U₃ energize and release switches A, C and U respectively to their normal position. Magnet B₅, energized, causes switch B to release which also restores springs B₄. With springs B₄ normal, relay 205 releases as previously set forth and switch B then advances its first step.

Upon the release of switch A, the off-normal springs A₂ and A₅ restore to their unoperated position thereby respectively opening the locking and the operating circuit for relay 217, which releases. The A₂ springs in normal position close the operating circuit for relay 204 which locks to ground over the right contacts of relay 208. Relay 204, in operating, closes previously traced operating circuits for vertical magnet A₁ and rotary magnet C₂. Magnet A₁, in energizing, advances the brushes of switch A one vertical step and, due to the opening of its contacts, opens the short circuit on the left winding of relay 211 which operates over a previously traced circuit. Magnet C₂, in energizing, advances brush C₁ to contact the first terminal of its bank. The off-normal springs A₂, which operate on the first vertical step of switch A, open the operating circuit for relay 204. Relay 211, in operating, opens the circuit through magnets A₁ and C₂. When magnet A₁ de-energizes, it closes its contacts thereby closing the short circuit around the left winding of relay 211 which releases. Relay 211, in releasing, again closes the operating circuits for magnets A₁ and C₂ and the brushes of switch A take a second vertical step and brush C₁ advances to the second terminal of its bank. The A₁ magnet, in energizing, opens its contacts which removes the short circuit from the left winding of relay 211. Relay 211 operates and opens the circuits through magnets A₁ and C₂ which de-ener-

gize. When the contacts of magnet A₁ close, the left winding of relay 211 is short-circuited but relay 211 remains operated through its right winding, winding of relay 208 which operates, brush C₁ and its second bank terminal, second bank terminal and brush T₁, to ground over the left contacts of relay 204. Relay 208, in operating, opens the locking circuit for relay 204 which releases, and closes the circuit from ground over its left front contact, right armature and back contact of relay 217, to battery through rotary magnet A₃. Magnet A₃ energizes and advances the brushes of switch A to contact the first set of terminals of the second level of the A switch banks. Relay 204, in releasing, opens the circuit through the windings of relays 211 and 208. Relays 211 and 208 release, relay 208 opening the A₃ magnet circuit and closing the locking circuit for relay 204, and relay 211 closing, in part, the A₁ and C₂ magnet circuits.

The transmission lines which terminate on the first set of terminals of the second level of the banks of switch A are now connected to the B switch bank terminals associated with brush B₁. As the associated signal distortion measuring circuit continues to function, ground applications to conductor 213 cause the advance of switch B which progressively associates each transmission line with the repeaters and measuring circuits over conductor 209.

In a manner similar to that hereinbefore set forth, the continued applications of ground to conductor 213 cause switches A, B, C, T and U to function until the brushes of switch A have contacted each of the one hundred sets of TA, TB, TC, TD, TE and TF terminals and switch B has associated each of the six hundred transmission lines connected to the aforementioned terminals with the repeater and distortion measuring circuits. Brushes C₁ and T₁ control the number of vertical steps that the brushes of switch A take following the release of switch A after its brushes have contacted the ten sets of terminals in any particular bank level, since switch T advances one step for each operation of release magnet A₄ and since vertical magnet A₁ and rotary magnet C₂ must energize and release for the number of times corresponding to the number of the bank terminal in contact with brush T₁ at that time.

During each step of the foregoing operations, brushes B₂, T₂ and U₁ prepare the proper circuits for the group, tens and units lamps, respectively, so that the application of battery to conductor 214 by the measuring circuit, at any time, will cause signal 215 to sound, and the lamps associated with the particular line upon which excessive signal distortion has been encountered to light.

When brush T₁ reaches the tenth terminal of its associated bank, it closes the circuit from battery through the right winding of relay 218 to the left armature of relay 204 which is unoperated at that time. Upon the operation of relay 204 for the advance of the A switch brushes to the tenth levels of the A switch banks, relay 218 operates and locks through its left winding to ground over the operated contacts of the off-normal springs T₄. Relay 218, in operating, closes a circuit from battery at key 201, through the winding of release magnet T₅, right armature and contact of relay 218 to the sixth terminal of the bank associated with brush B₂.

After the brushes of switch A have advanced to the tenth sets of terminals of the tenth levels of the A switch banks, and after the B switch has

subsequently advanced brushes B₁ and B₂ to their sixth bank terminals, the ground over brush B₂ energizes the release magnet T₅. Magnet T₅, energized, causes the T switch to restore to its normal position at which time the off-normal springs T₄ also restore to normal. When springs T₄ restore, the locking circuit for relay 218 is opened and that relay releases. In addition, ground over the normally closed contacts of springs T₄ operates relay 203 through its right winding. The release of relay 218 opens the circuit through release magnet T₅. Relay 203, in operating, locks through its left winding and closes the circuit through magnet T₃ which causes brushes T₁ and T₂ to be advanced to the first terminal of their respective banks. Ground over brush T₂ short-circuits the left winding of relay 203 which releases since the circuit through its right winding was opened by the operation of off-normal springs T₄ upon the first step of switch T.

When magnet A₃ releases after the tenth rotary step on the tenth bank levels of switch A, relay 217 operates over the now operated tenth off-normal springs A₅. Relay 217, in operating, locks to ground under control of the operated A₂ springs and prepares the circuit for release magnet A₄. When ground is returned to conductor 213 at the termination of the distortion measurement of the six hundredth transmission line, rotary magnet B₃ is energized advancing switch B to the seventh step. Relay 205 operates from ground over brush B₂ and the seventh bank terminal. Relay 205, in operating, locks under control of the operated B₄ springs, and closes the energizing circuits for release magnets A₄, B₅, C₃ and U₃. Switches A, B, C and U restore to normal, in turn restoring off-normal springs A₂, A₅ and B₄ to normal. Springs A₅, restoring to normal, open the operating circuit for relay 217. Springs A₂, restoring to normal, open the locking circuit for relay 217 which releases, and also close the circuit through the winding of relay 204 which operates. Springs B₄, restoring to normal, release relay 205 by opening its locking circuit, and also operate relay 202 through its right winding.

From this point on, the circuit functions in the same manner as hereinbefore set forth from the beginning of the detailed description of the operation of Fig. 2, with the exception that relay 203 has already operated and released, switch T having taken its first step immediately upon its return to normal as previously noted.

The transmission lines, beginning with those terminating on the first terminals of the first level of the A switch banks, will be successively connected to the repeater and distortion measuring circuits, as previously set forth, the circuit of Fig. 2 functioning as long as key 201 remains operated.

Referring now to Fig. 3, this figure comprises the delay and regenerative repeater circuits and the signal distortion measuring circuits. The delay repeater circuit consists essentially of relays 303, 304 and 305, resistances 306 and 307, and condenser 308. The regenerative repeater consists essentially of the start-stop distributor D and relays 309 and 310. The distributor D is composed of a receiving ring and receiving segments 311, a sending ring and sending segments 312, a set of brushes 313 associated with the receiving ring and segments 311, and a set of brushes 314 associated with the sending ring and segments 312. A clutch 315, upon being released by latch 316, causes brushes 313 and 314 to make one complete revolution over their associated

rings and segments in a manner well known in the art. The signal distortion measuring circuit consists essentially of relays 317, 318, 319 and 320.

The interval during which signal distortion measurements are made on any transmission line is controlled by interrupter 321. This interrupter is arranged to close its contacts for approximately one second once each minute, the contacts being open during the remaining 59 seconds of the minute interval. Signal distortion measurements or any line are made during the 59 second open interval of the interrupter and, if no excessive distortion is encountered over that period, the following one second closure of interrupter 321 causes the measuring circuit and the associated circuit of Fig. 2 to function and pass on to the succeeding transmission line. Should excessive distortion be encountered during a measuring interval, the measuring circuit functions to lock in an indication of this condition, and the further operations of interrupter 321 are ineffective until the measuring circuit is manually released. The manner in which the foregoing operations take place will be subsequently set forth in detail.

For the purpose of illustrating the complete functioning of the circuits of Fig. 3, let it be assumed that a signal distortion measurement has just been made on a transmission line connected to these circuits over conductor 209 of Fig. 2, and that no excessive signal distortion was encountered on the signal impulses received over that line.

When the contacts of interrupter 321 now close at the end of the 59 second measuring interval, ground over the interrupter contacts operates relay 325 in an obvious circuit. Relay 325, in operating, connects ground over its front contact to battery through the left winding of relay 326, and also connects this same ground, over the right back contact of relay 320, to conductor 213. Relay 326 operates through its left winding, and the ground on conductor 213 of Fig. 2 causes the circuit of Fig. 2 to function, as hereinbefore set forth, and connect the next transmission line to conductor 209 of Fig. 2. Relay 325, by its operation, also opens the circuit from ground over its back contact, back contacts of relay 326, to battery through the left winding of relay 331 (previously operated as will later be described) and relay 331 releases. Relay 331, in releasing, connects negative battery, through resistance 328, over its right back contact to the winding of relay 330, and also connects negative battery, through resistance 329, over its left back contact, through the right winding of relay 326, to the armature of relay 302. Relay 331, in releasing, also opens the circuit to the armature of relay 319 and opens the circuit to the armature of the off-normal springs 332.

The particular transmission line on which signal distortion measurements are about to be made has now, by the functioning of the circuit of Fig. 2 in a manner previously described, been connected to conductor 209, and over this conductor to ground through the winding of polarized relay 302. Relay 326, at this time, is being held operated through its left winding. At the end of the one second closure, the contacts of interrupter 321 open and release relay 325. Relay 325, in releasing, opens the circuit through the left winding of relay 326, but relay 326 does not release immediately since it is of the slow-to-release type.

Relay 302, being polarized, operates its armature to contact its right or left contacts in unison with the incoming signal impulses received

over the printing telegraph transmission line connected to conductor 209 from Fig. 2. At all times when no signals are being transmitted, a marking current is applied to the line. The polarity of this marking current is such that the armature of relay 302 is held against the right contact of the relay. Each transmitted character is composed of a series of six impulses of which the first impulse (known as the start pulse) is always spacing. An impulse of spacing current causes the armature of relay 302 to make contact with its left contact. The polarity and arrangement of the remaining five impulses following the start pulse is dependent upon the particular character being transmitted. The armature of relay 302 will, therefore, be on the right contact of the relay for all marking impulses and during the interval between transmitted characters, and will be on its left contact for all spacing impulses.

Relay 302, on its right contact in response to marking current or impulses, connects grounded negative battery through resistance 335, over three parallel paths, namely, to the right winding of relay 326, to ground through resistances 306 and 307 and the lower winding of relay 303, and to the receiving ring 322 of distributor D. When on its left contact, in response to spacing impulses, relay 302 connects grounded positive battery through resistance 334 over the same parallel paths to the aforementioned points.

The series of impulses incoming over the line, representing successive characters, may be transmitted in rapid succession under control of a tape transmitter or a continuously operated keyboard, or they may be transmitted slowly from a keyboard in which instance a considerable interval of marking current separates each impulse series.

As stated hereinbefore, upon the release of relay 325 the circuit through the left winding of relay 326 is opened but, since relay 326 is slow-to-release, the relay remains operated for an interval. Also, the previous release of relay 331 connected grounded negative battery through resistance 329 and through the right winding of relay 326 to the armature of relay 302. Relay 302, therefore, in response to series of incoming impulses in rapid succession, contacts the grounded positive battery on its left contact with sufficient frequency to hold relay 326 energized through the right winding of that relay. Relay 326, remaining operated, prevents the operation of relay 331 upon the release of relay 325. The operation of the circuit under this condition will be set forth in detail later.

Assume that the series of impulses, corresponding to characters, are being transmitted slowly from a manually operated keyboard. Relay 302, in following the incoming impulses, will, therefore, be off its left contact for a sufficient interval (in response to the marking current between characters) to allow relay 326 to release. Relay 326, in releasing, causes relay 331 to operate in a circuit from grounded battery through the left winding of relay 331, normally closed contacts of relay 326, to ground over the back contact and armature of relay 325. Relay 331, in operating, removes the battery from the right winding of relay 326, removes the battery from the winding of relay 330, and connects the ground from the armature and back contact of relay 325 to the armature of relay 319, through the contacts of key 318.

Upon the first incoming impulse, which is the start pulse, relay 302 operates to its left contact thereby connecting grounded positive battery, 75

through resistance 334, to conductor 333. This positive potential operates the clutch release magnet 324 in a circuit over conductor 333, receiving ring 322, brush 313, start receiving segment 323, to negative potential through the winding of magnet 324 to grounded negative battery. Magnet 324, in energizing, disengages latch 316 from clutch 315 and the distributor brushes 313 and 314 now make one revolution over their associated rings and segments. The speed at which the brushes revolve is uniform and the speed of the driving motor (not shown) of distributor D as well as the speed of the driving motor of the distributor at the distant transmitter is held to within approximately ± 1 per cent by a centrifugal governor associated with each motor.

As soon as brush 313 passes off segment 323, the circuit through magnet 324 is opened. Magnet 324 de-energizes and latch 316 restores to normal in which position, at the conclusion of a complete revolution of the brushes, it re-engages clutch 315 to hold the brushes until the next start pulse is received.

The receiving segments 341 to 346, inclusive, are so placed with respect to the stop position of brush 313 that the brush is in contact with any receiving segment only during the middle portion of the received impulse. The sending segments 351 to 356, inclusive, are so arranged with respect to brush 314 that this brush does not contact a particular sending segment until receiving brush 313 is just leaving or has just left the corresponding receiving segment. With respect to the received impulses, therefore, the signals to be regenerated by sending brush 314 and its associated ring and segments will be delayed by approximately one-half of the time required to transmit one signal element.

When brush 313 reaches the first receiving segment 341 a circuit is completed from the armature of relay 302, over receiving ring 322, brush 313, receiving segment 341, to ground through the upper winding of polarized relay 309 and through resistance 336. Relay 309, at this time, is locked in the position of its last previous operation in a circuit from ground through resistance 350, lower windings, armature and left or right contact of relay 309, to grounded positive or grounded negative battery through resistance 337 or 338 respectively. If the polarity of the current in the aforementioned circuit through the upper winding of relay 309 is in the direction opposite to the last previous current flow through that winding, relay 309 will unlock and move its armature to its opposite contact and will again lock through its lower winding in that position. If the polarity of the current through the upper winding is the same as the last previous current flow through that winding, relay 309 remains locked with its armature on the contact to which it last moved. The armature of relay 309, therefore, follows the operation of the armature of relay 302 for each alternate impulse and connects, depending upon its position, positive or negative battery, through resistances 337 and 338 respectively, over its left or right contact and armature, to sending segments 351, 353 and 355. Brush 314, at this time, is in contact with sending segment 357 which is connected to grounded positive battery which will operate polarized relay 318 to its left hand contact to repeat the start pulse. As receiving brush 313 is leaving segment 341, sending brush 314 contacts the first sending segment 351 thereby completing a circuit from positive or negative battery on the armature of

relay 309, over the first sending segment 351, brush 314, sending ring 339, to ground through the winding of relay 318. Depending on the polarity of the current through its winding, relay 318 operates its armature to its opposite contact or keeps its armature on the contact already made.

As the distributor brushes 313 and 314 continue to advance, brush 313 contacts the second receiving segment 342, this closure corresponding in time to the middle portion of the second incoming impulse following the start pulse. Grounded positive or grounded negative battery, depending upon the position of the armature of relay 302 in response to the incoming impulse, is connected over the contact and armature of relay 302, conductor 333, receiving ring 322, brush 313, receiving segment 342, to ground through the upper winding of relay 310 and through resistance 340. In a manner similar to that described for relay 309, relay 310 will either remain locked or will move its armature to the opposite contact and then lock, depending upon the polarity of the current through its upper winding. The locking circuit for relay 310 may be traced from ground through resistance 349 and the lower winding, armature and left or right contact of the relay, to either grounded positive or grounded negative battery through resistance 347 or 348 respectively. The armature of relay 310 follows the operation of the armature of relay 302 for the impulses incoming over receiving segments 342, 344 and 346. Relay 310, depending upon the position of its armature, connects grounded positive or grounded negative battery, through resistances 347 and 348 respectively, over its left or right contact and armature, to sending segments 352, 354 and 356.

As receiving brush 313 leaves receiving segment 342, sending brush 314 leaves sending segment 351 and moves on, contacting the second sending segment 352 which corresponds to receiving segment 342. The positive or negative potential from the armature of relay 310 is now applied to the circuit extending over segment 352, brush 314, sending ring 339, to ground through the winding of polarized relay 318. Relay 318, as in the case of the preceding impulse, will either keep its armature stationary or will move it to the opposite contact, depending upon the current polarity and on the position assumed by the armature during the previous impulse.

In a manner similar to that hereinbefore described, the three remaining impulses of the series which compose the particular character being transmitted, plus a sixth impulse known as the stop pulse, are regeneratively repeated through the winding of relay 318; receiving brush 313 alternately associating the armature of relay 302, over receiving segments 343, 344, 345 and 346, with the upper windings of relays 309 and 310, and sending brush 314 alternately associating the armatures of relays 309 and 310, over sending segments 353, 354, 355 and 356, with the winding of relay 318.

Since sending segments 351 to 356, inclusive, are of uniform length and uniformly spaced, it will be obvious that the regenerated impulses produced in the winding of relay 318 correspond to the original undistorted impulses being transmitted from the distant end of the transmission line. As previously stated, however, the regenerated signals lag the incoming signals by approximately one-half an impulse length, since the sending brush 314 does not contact a par-

ticular sending segment until the receiving brush 313 is leaving or has just left the corresponding receiving segment, the receiving segment at that time carrying the middle portion of the particular impulse. Due to this lag in the regenerated signal, it is necessary to introduce a corresponding lag in the incoming signals which are to be compared with the undistorted regenerated signals during the signal distortion measuring interval. This lag in the incoming signals is produced by the delay repeater circuit which functions in the manner hereinafter set forth.

The delay repeater circuit operates simultaneously with the regenerative repeater circuit, both circuits functioning from the same impulses of positive and negative potential supplied over conductor 333 when relay 302 responds to the signal impulses incoming over conductor 209.

Assume that the last prior operation of relay 302 was in response to marking current. The armature of relay 302, therefore, moved from its left to its right contact thereby reversing the polarity of the current in the circuit through resistances 306 and 307 and the lower winding of relay 303. In response to this change in polarity, relay 303, after an interval obtained in a manner subsequently explained, unlocked and moved its armature from its left to its right contact. Relay 303 then locked in that position in a circuit from ground through resistance 361, upper winding, armature and right contact of relay 303, to grounded negative battery through resistance 359. The operation of relay 303 removed the positive battery, through resistance 358, from conductor 364 and connected negative battery, through resistance 359, and over its right contact and armature, to conductor 364. This changed the polarity of current in the circuit through resistance 360 and through the winding of polarized relay 317, and caused relay 317 to move its armature from its left contact to its right contact. The change in the potential polarity on conductor 364 also caused a surge through condenser 362, in a circuit through resistance 363 and the windings of biased polarized relays 305 and 304 to ground. Relays 304 and 305 are oppositely poled with respect to their series circuit, and the aforementioned surge was in a direction which caused relay 304 to momentarily move its armature to contact its left contact. Condenser 308 had started to charge from the grounded negative battery over the right contact and armature of relay 302 and through resistance 306 to ground on the other plate of the condenser. The momentary closure of the left contact of relay 304 caused the complete charging of condenser 308 from grounded negative battery through resistance 365 and over the left contact and armature of relay 304 to the upper condenser plate, the lower plate being grounded.

As has just been set forth, therefore, prior to the first incoming impulse of the signal impulses about to be delayed, the armatures of relays 302, 303 and 317 are contacting their respective right contacts, and condenser 308 is completely charged, with the negative charge on its upper plate connecting to the junction of resistances 306 and 307.

When relay 302 now operates its armature from its right to its left contact, in response to the first or start impulse (which is always spacing), the potential on conductor 333 is changed from negative to positive. Since the junction point of resistances 306 and 307 is at negative potential at this time, due to the existing charge

on condenser 308, the application of positive potential to conductor 333 and through resistance 306 does not immediately cause current to flow in the positive direction through the lower winding of relay 303. Condenser 308 first discharges in a circuit through resistance 306, armature and left contact of relay 302, to grounded positive battery through resistance 334 and, when discharged, again starts charging to this positive potential which is the reverse, in polarity, of the preceding charging potential. After condenser 308 has recharged to a certain point, the junction of resistances 306 and 307 becomes sufficiently positive with respect to ground that the current flow in the lower winding of relay 303, in the positive direction, is sufficient to overcome the effect of locking current in the upper winding of that relay, and relay 303 will operate its armature away from its right contact and move to its left contact.

When relay 303 transfers its armature from right to left, it reverses the polarity of the potential on conductor 364, operating relay 317 to its left contact, and causing a surge through condenser 362, resistance 363 and the windings of polarized relays 305 and 304. This surge is in the direction which causes the momentary operation of relay 305. Relay 305 momentarily completes the circuit from grounded positive battery through resistance 366, left contact and armature of relay 305, to the upper plate of condenser 308 thereby completing the charging of that condenser. Relay 303, in operating to its left contact, locks in that position in a circuit from grounded positive battery, through resistance 353, left contact, armature and upper winding of relay 303, to ground through resistance 361.

The function of relays 304 and 305 is to provide for the rapid and complete charging of condenser 308 to either polarity of charge upon each operation of relay 303 and prior to the subsequent operation of relay 302, thereby insuring a uniform delay interval for each impulse.

Succeeding impulses repeated to the delay repeater circuit by relay 302 cause relays 303, 304, 305 and 317 to function in a manner similar to that just previously described for the first impulse. Marking impulses, which operate relay 302 to its right contact, cause relay 303 to operate to its right contact after condenser 308 discharges and partially recharges, and relay 303, after this delay interval, causes relay 317 to operate to its right contact and also momentarily operates relay 304 to complete the charging of condenser 308. Spacing impulses cause the circuit to function in a manner identical with that described for the first or start impulse, which was spacing.

In the foregoing manner, relay 317 follows the incoming impulses in agreement with the operation of relay 302 but delayed by the interval required to discharge condenser 308 and recharge that condenser, in the opposite polarity, to a point where the current through the lower winding of relay 303 is effective in unlocking that relay and operating it to its opposite contact. This delay interval is equivalent to the lag of approximately one-half an impulse length which is introduced in the regenerated signals by the regenerative repeater circuit as was hereinbefore set forth.

Now, therefore, under control of the operations of relay 302 in response to the incoming signals over the transmission line, relay 318 is operating from the retransmitted undistorted signals produced by the regenerative repeater cir-

cuit, while relay 317 is operating from the incoming signals which have been delayed to compensate for the lag present in the regenerated signals. If no distortion is present in the incoming signals,

5 relay 317 will operate in unison with relay 318, and the ground from the armature of relay 318 will be removed from the armature of relay 317 only during the interval required for the transfer of the armatures of relays 317 and 318 from
10 the left to the right contacts and vice versa. If distortion is present in the incoming signal impulses, the operation of relay 317 will no longer be in synchronism with the operation of relay 318. This results in prolonging the interval during
15 which the ground over the armature of relay 318 is removed from the armature of relay 317.

The ground supplied over the armatures and contacts of relays 317 and 318, when both of these relays are in their same respective positions, connects to one side of condenser 369, thereby short-circuiting that condenser. This same ground is also connected to grounded negative battery through the upper winding of polarized relay 319 and resistance 367, causing a current flow through
25 the upper winding of relay 319 in a direction which holds the armature of that relay on its right contact. When the ground is removed from the armature of relay 317, during the transfer time of the armatures of relays 317 and 318 as they are operating in synchronism, the short circuit is removed from condenser 369. The current in the upper winding of relay 319, however, does not immediately fall to zero since condenser 369
30 charges from the grounded negative battery through that winding and temporarily maintains the current flow. Before the charging current flow ceases, due to the complete charging of condenser 369, relays 317 and 318 will have again closed the circuit to ground over their armatures and contacts to short-circuit condenser 369 and
40 reestablish the current flow through the upper winding of relay 319.

Assume now that distortion is present in the incoming signal impulses. Relay 317 will, therefore, due to the distortion, get out of step with
45 relay 318 as these two relays are repeating the signal impulses. This prolongs the interval during which the ground is removed from condenser 369 and from the upper winding of relay 319. If this interval is of sufficient duration, condenser 369 completely charges before the energizing circuit for the upper winding of relay 319 is re-established and the current through that winding, therefore, falls to zero.

55 The next-to-upper winding of relay 319 is permanently energized in a circuit from ground through the winding and through resistance 368 to grounded negative battery, and this winding is so wound that its effect on relay 319 opposes that of the upper winding of that relay. When the upper winding current, therefore, falls to zero, as stated above, the next-to-upper winding of relay 319 becomes effective and moves the armature of the relay off its right contact. Prior to
60 this time the left winding of transformer 372 has been energized in a circuit from grounded negative battery, left winding of the transformer, right contact and armature of relay 319, contacts of key 378, middle left armature and front contact of the operated relay 331, and back contact and armature of the unoperated relay 325, to ground. When relay 319 therefore opens its right contact, the circuit through the left winding of transformer 372 is opened thereby inducing a surge
70 of current through the lower winding of relay 319 over the secondary winding of transformer 372. This surge is in the proper direction to immediately operate the armature of relay 319 to the left contact of that relay.

When the armature of relay 319 closes to its
5 left contact, a circuit is completed from the previously traced ground on that armature, over the left contact of relay 319 to grounded battery through the contacts of key 378 and the winding of relay 320. This ground is also connected over
10 the normally closed right contacts of relay 320, and through resistance 371 and the next-to-lowermost winding of relay 319 to grounded negative battery thereby providing a locking circuit for relay 319 until the complete operation of relay
15 320 has been effected.

Relay 320, in operating, locks over its right front contact and armature to ground over the upper armature and back contact of key 373 and opens the locking circuit for relay 319. In addition, the operation of relay 320 connects battery over its left armature and front contact to conductor 214 of Fig. 2, thereby causing an audible alarm and a visual indication of the signal distortion encountered, in the manner hereinbefore
25 described under the detailed operation of Fig. 2. Relay 320, in operating, also opens the circuit from conductor 213, over its outer right armature and back contact, to the front contact of relay 325, thereby rendering the operation of relay 325, under control of interrupter 321 at the conclusion of the measuring interval, ineffective in advancing the circuits of Fig. 2 to the succeeding transmission line. The alarm indications remain locked-in under control of key 373.

The length of the interval during which the ground over the armatures and contacts of relays 317 and 318 can be removed from the upper winding of relay 319, before causing that relay to function and cause an alarm to be given as hereinbefore set forth, is controlled by the charging time of condenser 369. This interval may be varied by changing the capacity of condenser 369 which is variable. Condenser 369 may therefore be set at a value of capacitance such that any predetermined corresponding amount of signal distortion causes the measuring circuit to function and cause an excessive distortion alarm to sound. It will be obvious that the alarm indicates that the distortion encountered on the transmission line under observation is equal to or exceeds the amount of distortion predetermined by the adjustment of condenser 369.

If it is now desired to quantitatively measure the distortion present in the incoming signals, key 378 is operated. Key 378, in being operated, transfers the conductor on the armature of relay 319 from the left middle armature of relay 331, to ground over the upper front contact of key 378. The conductor from the left contact of relay 319 is transferred, by the operation of key 378, from the winding of relay 320 to grounded battery through lamp 379. Relay 320 does not release since it is locked in its operated position under control of key 373.

As the armature of relay 319 now moves to its left contact in response to the excessive signal distortion, lamp 379 lights from the ground on the armature of relay 319. By changing the capacity of the variable condenser 369 to a point where lamp 379 no longer lights, a measurement of the maximum distortion present in the incoming signal is obtained. Condenser 369 may be provided with an indicator calibrated to give the approximate percentage of signal distortion.

At the conclusion of the particular excessive distortion measurement, key 378 is restored to the normal position. Key 378, in releasing, opens the circuit to lamp 379, reconnects the conductor from the left contact of relay 319 to the winding of relay 320, disconnects the direct ground from the armature of relay 319, and again connects the armature of relay 319 to the left middle armature of relay 331. Key 373 is now momentarily operated. The operation of key 373 opens the locking circuit for relay 320 which releases, thereby removing grounded battery from conductor 214 of Fig. 2 which silences the audible alarm and extinguishes the visual signal of Fig. 2. The operation of key 373 also connects ground to conductor 213 of Fig. 2, causing the circuits of Fig. 2 to function as previously described and connect the succeeding transmission line to conductor 209.

Assuming that no excessive signal distortion is encountered on the transmission line under observation, relays 317 and 318 operate in unison during the measuring interval and remain in synchronism sufficiently to prevent the complete charging of condenser 369. Relay 319, therefore, does not move its armature off its right contact. At the conclusion of the 59-second open interval of interrupter 321 the interrupter contacts close and operate relay 325. Relay 325, in operating, removes the ground from the armature of relay 319, and connects ground over its armature and front contact to battery through the left winding of relay 326, and to conductor 213 over the right back contact and armature of relay 320. The ground over conductor 213 of Fig. 2, causes Fig. 2 to function as previously described and connect the next transmission line to conductor 209 of Fig. 2. From this point on, the operation of the circuit is identical to that hereinbefore set forth, from the corresponding point of the grounding of conductor 213 at the outset of the description of the detailed operation of Fig. 3.

In the foregoing description of the operation of Fig. 3 it was assumed that the series of incoming impulses, corresponding to characters, were being transmitted slowly from a distant manually operated keyboard. Under that condition the armature of relay 302, in following the incoming impulses, was therefore off its left contact for a period sufficient to allow relay 326 to release. When relay 326 released it operated relay 331. Relay 331 in turn opened the circuit from battery through the right winding of relay 326 and thereby prevented the further operation of relay 326 at that time.

Assume now, instead, that the incoming series of impulses are being transmitted in rapid succession from the distant end of the line under control of a continuously operated keyboard or under control of a tape transmitter. As previously set forth, under this condition, upon the opening of the contacts of interrupter 321 at the beginning of the measuring interval, the release of relay 325 opens the circuit through the left winding of relay 326 but relay 326 does not release since the armature of relay 302 is on its left contact for intervals of sufficient length to hold relay 326 energized through its right winding. Relay 326, remaining operated, prevents the operation of relay 331 upon the release of relay 325 at the beginning of the measuring interval.

With relay 331 released, the circuit to the armature of relay 319 is open and grounded negative battery, through resistance 328 is connected

to the winding of relay 330 over the right armature and back contact of relay 331.

The first incoming impulse over the transmission line, which is the start pulse, causes relay 302 to operate to its left contact and complete the circuit from grounded positive battery through resistance 334, left contact and armature of relay 302, conductor 333, distributor receiving ring 322, brush 313 and receiving segment 323, to grounded negative battery through the winding of clutch release magnet 324 and also to grounded negative battery through the winding of relay 330. Relay 330, in operating, closes the circuit from ground on the armature and over the back contact of relay 325, operated contacts of relay 326, contact and armature of relay 330, to grounded battery through rotary magnet 375.

Magnet 375, in energizing, causes brush 376 of switch S to step to the first terminal of its associated bank at which time the off-normal springs 332 operate and prepare the circuit from grounded battery through the winding of release magnet 377 to the inner armature of relay 331.

Since the start pulse operated the clutch release magnet 324, the brushes of distributor D revolve through one revolution and regeneratively repeat the incoming impulses to relay 318 in the manner previously described. Simultaneously, relays 303, 304 and 305 function as hereinbefore set forth, and cause relay 317 to follow the delayed incoming impulses. The distortion measuring circuit is ineffective, however, since there is no ground on the armature of relay 319 due to the non-operated position of relay 331.

When brush 313 moved off segment 323 it opened the circuit through the windings of clutch release magnet 324 and relay 330. Clutch release magnet 324, released, causes the distributor brushes to come to rest at the conclusion of one revolution. Relay 330, in releasing, opens the circuit through the rotary magnet 375 of switch S.

The start pulse of the second series of incoming pulses causes the distributor brushes to make another revolution and also again operates relay 330 which, in turn, energizes rotary magnet 375 thereby causing the brush 376 of switch S to move to the second terminal of its associated bank.

The foregoing cycle of operations will continue, each operation of relay 330 causing brush 376 to advance to the next terminal of its bank, until brush 376 contacts its tenth bank terminal at which time ground over brush 376 and the tenth terminal is connected to grounded battery through the right winding of relay 331.

Relay 331, in operating through its right winding, opens the circuit to the winding of relay 330 to prevent further operations of that relay, removes the negative potential from the right winding of relay 326 which permits relay 326 to release, and connects ground from over the armature and back contact of relay 325, over the left middle armature and front contact of relay 331 to the armature of relay 319.

Relay 326, in releasing, closes the circuit from ground over the armature and back contact of relay 325, over its normal contacts to grounded battery through the left winding of relay 331 and over the inner right front contact and armature of relay 331, over the operated off-normal springs 332, to grounded battery through the winding of the release magnet 377 of switch S.

Release magnet 377, in energizing, causes in any well known manner, brush 376 to restore to its normal position at which time the off-normal

springs 332 also restore to their normal non-operated position. As brush 376 leaves the tenth bank terminal, in restoring to normal, the circuit through the right winding of relay 331 is opened.

5 Relay 331 does not release however since it is being held operated through its left winding over the previously traced circuit established upon the release of relay 326.

10 Since ground is now connected to the armature of relay 319, the distortion measuring circuit is effective and subsequent series of impulses incoming over the transmission line under observation cause the regenerative repeater, delay repeater and signal distortion measuring circuits to function in a manner identical with that hereinbefore set forth for the functioning of these circuits in response to slowly transmitted impulse series.

15 The purpose of delaying the start of the signal distortion measurements when the incoming series of signal impulses are being transmitted in rapid succession is to prevent the false operation of relay 320 upon the transfer of the measuring circuit from one transmission line to another. Assume, for example, that a transmission line is connected to conductor 209 during the middle of a series of impulses incoming over that line, and that the first impulse effective in operating relay 302 is a marking impulse. Since a start pulse and a spacing impulse are identical, the regenerative repeater will not start to function immediately but will await the first spacing impulse, after which the operations of relays 317 and 318 may be out of synchronism with respect to complete series of impulses. This condition would result in the possibility of a false excessive signal distortion indication, even though no excessive distortion was actually present in the incoming signals, were it not for the ineffectiveness of the measuring circuit at this time due to the absence of ground from the armature of relay 319. The interval introduced by the stepping of switch S from its first to its tenth bank terminal (corresponding to ten revolutions of the brushes of distributor D) provides ample time for distributor D to come into step with the incoming signal. In the foregoing manner the possibility of false excessive signal distortion indications is guarded against.

20 Referring now to Fig. 4, this figure comprises a delay repeater circuit, a regenerative repeater circuit, and a signal distortion measuring circuit which function in the same general manner as the corresponding circuits of Fig. 3. The points of difference between Fig. 4 and Fig. 3 are in the delay repeater and signal distortion measuring circuits, which in the case of Fig. 4 employ vacuum tubes.

25 The regenerative repeater circuit of Fig. 4 functions in the same manner as that hereinbefore set forth for the regenerative repeater of Fig. 3. The start-stop distributor D₁ is identical with distributor D of Fig. 3, and the manner in which the incoming signals are regeneratively repeated from the contacts of relay 332 to the winding of relay 318 is the same in both cases. The individually numbered circuit elements 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 420, 421, 422, 423, 424, 425, 426, 428, 429, 430, 431, 433, 434, 435, 437, 438, 439, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456 and 457 function in a manner identical with the correspondingly numbered elements 309, 310, etc., of the regenerative repeater circuit of Fig. 3.

30 The transmission lines are connected to conductor 209 of Fig. 2 which conductor is, for the purpose of describing Fig. 4, part of conductor

209' of Fig. 4 and, after distortion measurements have been made, a ground is connected to conductor 213 of Fig. 2 either by the operation of relay 425 or by the operation of key 473. Conductor 213 of Fig. 2 is, for the purpose of describing Fig. 4, part of conductor 213' of Fig. 4. The ground on conductor 213' causes the circuits of Fig. 2 to advance to the succeeding transmission line as hereinbefore set forth in the description of Fig. 2. If excessive distortion is encountered, 5 grounded battery is connected over conductor 214' to conductor 214 of Fig. 2 to give an audible alarm and a visual indication of the condition as outlined under Fig. 2.

10 The operations and functions of interrupter 421, relays 420, 425, 426, 430 and 431, resistances 428 and 429, and key 473, in controlling the distortion measuring period and in connecting ground to conductor 213' and battery to conductor 214', are identical with the operations and functions of the correspondingly numbered interrupter 321, relays 320, 325, etc., of Fig. 3.

15 The manner in which relays 426 and 431, and magnets 475 and 477, brush 476 and off-normal springs 432 of switch S₁ function, in delaying the start of signal distortion measurements when the transmitted impulse series are incoming in rapid succession, is identical with that set forth for the correspondingly numbered relays, magnets, brush and springs of Fig. 3.

20 Relays 402 and 403 operate in series under control of the impulses incoming over conductors 209 and 209'.

25 In response to the incoming signal impulses, the armatures of relays 402 and 403 contact their respective right or left contacts, the left contacts for spacing and the right contacts for marking. Impulses of positive and negative polarities over the contacts and armature of relay 402 cause the distributor D₁ and relays 409 and 410 to function and regeneratively repeat corresponding undistorted impulses through the winding of relay 418 in the manner hereinbefore described.

30 Simultaneously with the regeneration of the undistorted signal impulses through relay 418, the received incoming signal impulses are repeated through the winding of relay 417 after being delayed by the delay repeater circuit for an interval of sufficient length to compensate for the lag in the regenerated signal impulses in the following manner.

35 Prior to the first incoming impulse the armature of relays 403 and 404 are contacting their respective right contacts. Grounded negative battery over the armature and right contact of relay 404, right contact and armature of relay 403, is connected to the grid or control electrode of vacuum tube 407. The cathode or filament of tube 407 is normally energized in a local circuit. The negative potential on the grid of the tube at this time is sufficiently large to prevent any flow of current in the anode circuit of the tube. The negative battery over the contacts and armatures of relays 403 and 404 is also connected to one side of rheostat 460 and to one plate of condenser 459 and this condenser is completely charged in a circuit extending to grounded positive battery on its opposite plate.

40 When the armature of relay 403 now moves to its left contact in response to the first spacing impulse, the negative potential source is disconnected from the grid of tube 407 and from the upper plate of condenser 459. Condenser 459 starts discharging through rheostat 460 thereby continuously diminishing the negative potential

on the grid of tube 407. Condenser 459 completely discharges and its upper plate and the grid of tube 407 finally assume the positive potential of the battery connected to the lower plate of condenser 459. Current now flows from ground on the cathode and over the cathode-anode circuit of tube 407, through the middle winding of relay 406 to grounded positive battery over the left contact and armature of relay 405. Relay 406, prior to this flow of current through its middle winding, was locked with its armature on its right contact in a circuit from grounded negative battery through resistance 462, right contact, armature and upper winding of relay 406, to ground through resistance 480. The flow of current through the middle winding of relay 406 is of sufficient amount and in the proper direction to counteract the effect of the locking current through the upper winding, and the armature of relay 406 now moves from its right to its left contact. Relay 406 locks in this position in a circuit from grounded positive battery through resistance 461, left contact, armature and upper winding of relay 406, to ground through resistance 480.

When the armature of relay 406 moves from its right to its left contact it changes the potential on conductor 481 from negative to positive thereby reversing the direction of the current flow in the circuit extending through the windings of relays 404, 405 and 417 to ground through resistance 466. Due to this current flow reversal, the armature of relays 404 and 417 move from their right to their left contacts and the armature of relay 405 moves from its left to its right contact.

With the armature of relay 404 on its left contact, grounded negative battery is again connected over the armature and left contact of that relay, over the left contact and armature of relay 403, to both the upper plate of condenser 459 and the grid of tube 407 through resistance 458. Condenser 459 charges, its upper plate becoming negative, and the current over the cathode-anode circuit of tube 407 falls to zero due to the negative potential on the grid of the tube. Relay 406 remains with its armature on the left contact however, since the relay is locked in that position by the previously traced flow of current through its upper winding.

With the armature of relay 405 on its right contact, the circuit through the middle winding of relay 406 is open and positive potential is connected through the lowermost winding of relay 406 to the anode of tube 407. The middle and the lowermost winding of relay 406 are connected in circuit in opposite directions with respect to their effect on the armature of the relay. A flow of current through the lowermost winding of the relay, as will subsequently take place, will therefore cause the armature to move in the direction opposite to that caused by the flow of current through the middle winding of the relay.

As previously stated, the reversal of the polarity of the potential on conductor 481 causes the armature of relay 417 to move from its right to its left contact which brings the position of that armature into agreement with the position to which the armature of relay 402 moved in response to the first incoming impulse.

Assuming now that the second incoming impulse is marking, the armatures of relays 402 and 403 move from their left to their right contacts in response to that impulse. Relay 402, in operating, reverses the polarity of the potential on

conductor 433 and causes the second impulse to be regeneratively repeated to the winding of relay 418 as previously set forth. Relay 403, in operating, disconnects the source of negative potential from condenser 459 and from the grid of tube 407. Condenser 459 discharges and, after an interval, the upper plate of the condenser and the grid of tube 407 become positive, as hereinbefore described, and current flows from ground over the cathode-anode circuit of tube 407, through the lowermost winding of relay 406, to grounded positive battery over the right contact and armature of relay 405. The current in the lowermost winding of relay 406 opposes and overcomes the locking current flowing in the uppermost winding of the relay, and the armature of relay 406 therefore moves from its left to its right contact. Relay 406 locks from grounded negative battery through resistance 462, over the right contact, armature and upper winding, to ground through resistance 480. Relay 406, in operating in the opposite direction, reverses the polarity of the potential on conductor 481 which, in turn, reverses the current flow through the windings of relays 404, 405 and 417. Relay 404, in operating, again impresses the negative potential on condenser 459 and onto the grid of tube 407 thereby causing the current in the cathode-anode circuit of the tube to cease flowing. Relay 405, in operating, transfers the anode circuit of tube 407 from the lowermost winding of relay 406 to the middle winding of that relay. Relay 417, in operating, moves its armature to its right contact in agreement with the position of the armature of relay 402 in response to the marking impulse.

Succeeding incoming impulses cause relays 403, 404, 405, 406 and 417, and tube 407 and condenser 459 to function in the same manner as described for the first two incoming impulses. Relay 417 follows the operations of relays 402 and 403, its armature moving to the same respective position as the armatures of relays 402 and 403 in response to each impulse. The impulses to which relay 417 responds are, however, delayed by the interval required for the potential on the grid of tube 407 to change from negative to positive upon each reversal of the polarity of the potential supplied over the armature of relay 403. Since this interval is dependent upon the discharge time of condenser 459 which controls the grid potential of tube 407, its length is determined by the capacity of condenser 459 and the resistance value of rheostat 460. The values of condenser 459 and rheostat 460 are so chosen that the impulses repeated through the winding of relay 417 are delayed sufficiently to compensate for the lag introduced by the regenerative repeater into the undistorted impulses which are simultaneously being repeated through the winding of relay 418.

The potential on the grid of tube 407 upon each discharge of condenser 459 is of such a value that the anode current flowing through either the lowermost or middle winding of relay 406 is greatly in excess of that required to overcome the effect of the opposing locking current and just operate the relay in the opposite direction. The purpose of this excess in operating current will be subsequently set forth. The function of resistance 458 is to prevent excessive grid currents on tube 407 upon the discharge of condenser 459.

When condenser 459 is charged, with its upper plate at negative potential, the negative potential

on the grid of tube 407 is greater than that required to just reduce the anode current of the tube to zero, thereby preventing any flow of current in the operating windings of relay 406 during a considerable portion of the discharge time of condenser 459. Therefore, when condenser 459 discharges, there is first a comparatively long period of no current through either operating winding of relay 406 followed by a rapid rise in anode current to a large ultimate amount. This rapid build-up of operating current through either operating winding of relay 406, to a point in excess of the amount required to just unlock and oppositely reoperate the relay, minimizes the effects of any inequality in the voltages of the positive and negative locking potentials for relay 406 and also minimizes any difference which may exist in the magnetic effectiveness of the middle and lowermost operating windings of the relay. This insures a uniform delay interval upon each change of the positions of the armatures of relays 403 and 417 in response to a change from spacing to marking or vice versa.

With relay 417 following the delayed received incoming signal impulses and relay 418 following the undistorted regenerated signal impulses, excessive signal distortion measurements are made in the manner hereinafter set forth.

The filaments or cathodes of tubes 470 and 478 are energized in local circuits. The circuit of tube 470 and transformer 472 is so connected that it will oscillate when certain voltage conditions are obtained on the grid of tube 470. Normally, with the armatures of relays 417 and 418 on their same respective contacts; resistance 468 and condenser 469 are short-circuited in a circuit over the armatures and contacts of those relays. A negative potential, from the negative terminal of the battery connected to potentiometer 436, is applied to the grid return conductor of tube 470. Under this condition no oscillations take place in the circuit consisting of tube 470 and transformer 472.

When relays 417 and 418 operate in synchronism, that is, when the received line signals are perfect and the lag through the delay repeater equals that introduced by the regenerative repeater, the short circuit on resistance 468 and condenser 469 will be open only during the interval required for the armature of relays 417 and 418 to travel from their respective right contacts to the left contacts or vice versa. During this interval the negative potential on the grid of tube 470 will decrease due to the fact that condenser 469 will start to charge from the positive potential connected to its upper plate through resistance 467. This rate of negative potential decrease on the grid of tube 470 is controlled by the values of resistances 467 and 468, the capacity of condenser 469, and on the voltage of the positive potential connected to resistance 467. These values are so chosen that the point to which the grid potential of tube 470 is reduced during the travel time of the armatures of relays 417 and 418 is well down on the lower portion of the grid voltage-anode current characteristic curve of tube 470. Rheostat 483 is adjusted to a value such that tube 470 will not oscillate in response to the aforementioned grid potential reduction.

When relays 417 and 418 again close their armatures to either their respective left or right contacts, the potential on the grid of tube 470 again returns to its full initial negative value

as determined by the value of resistance 482 and by the setting of potentiometer 436 which at this time is on its zero position.

If no excessive distortion is present in the incoming signal, relays 417 and 418 continue to operate in response to the incoming impulses until the contacts of interrupter 421 close and cause relay 425 to operate. Relay 425, in operating, removes the ground from the armature of relay 419, operates relay 426 through the left winding of that relay, and connects ground over its armature and front contact, over the back contact and outer right armature of relay 420 and over conductor 213' to conductor 213 of Fig. 2. This ground causes the circuits of Fig. 2 to function, in the manner hereinbefore described, and advance to the next transmission line, connecting that line to conductor 209' of Fig. 4 in place of the line upon which signal distortion measurements have just been completed.

Assume now that distortion is present in the incoming signal impulses and that relays 417 and 418 therefore no longer operate in synchronism. Since the operations of relays 417 and 418 are now out of step, the period during which the short circuit around resistance 468 and condenser 469 is open is lengthened by an amount proportionate to the amount of distortion present in the signals.

As hereinbefore set forth, when the short circuit around resistance 468 and condenser 469 is opened, the negative potential on the grid of tube 470 starts decreasing since condenser 469 starts to charge in a circuit from positive potential through resistance 467 to the upper plate of the condenser, to negative potential on the lower plate of the condenser through potentiometer 436.

Should a sufficient interval elapse before the succeeding closure of the short circuit around resistance 468 and condenser 469, the negative potential on the grid of tube 470 decreases to the point where the circuit consisting of tube 470 and transformer 472 will break into oscillation. Normally, the negative potential applied to the grid of tube 478 through the right winding of transformer 440 is just sufficient to prevent any flow of current in the anode circuit of that tube. However, when tube 470 goes into oscillation, these oscillations are impressed on the grid of tube 478 through the windings of transformer 440 and the potential on the grid of tube 478 changes and causes current to flow through the cathode-anode circuit of the tube and through the uppermost winding of polarized relay 419.

The armature of relay 419 is normally on the right contact of the relay due to a flow of current in the circuit from ground, through the middle winding of the relay, and through resistance 463 to grounded negative battery. The flow of current in the uppermost winding of relay 419, over the cathode-anode circuit of tube 478, is in the direction which opposes and overcomes the current flowing in the middle winding of the relay and the relay armature therefore moves from its right to its left contact.

With the armature of relay 419 on its left contact, relay 420 operates in a circuit from ground over the armature and back contact of relay 425, over the front contact and left middle armature of relay 431, normally closed upper inner contacts of key 484, armature and left contact of relay 419, to battery through the winding of relay 420. Until relay 420 has completely operated, relay 419 locks in a circuit from

grounded negative battery through its lower winding, through resistance 464, over the normal contacts of relay 420, to the previously traced ground over the left contact and armature of relay 419.

Relay 420, in operating, locks over its front contact and inner right armature to ground over the upper armature and back contact of release key 473. Relay 420, in operating, also connects battery over its front contact and left armature, over conductor 214', to conductor 214 of Fig. 2 to cause the circuits of Fig. 2 to function and give an audible and a visual indication of the excessive signal distortion condition encountered. Relay 420, in operating opens its right normal contacts and thereby opens the locking circuit through the lowermost winding of relay 419 and the armature of that relay again moves to its right contact in response to the current through its middle winding. The excessive signal distortion alarm circuit remains locked in under control of release key 473.

If a quantitative measurement of the signal distortion encountered is desired, key 484 is operated. Upon the operation of this key its lower armature transfers the conductor which connects to the left contact of relay 419 from the winding of relay 420 to battery through lamp 485. Relay 420 remains operated since it is locked to ground over the upper contacts of key 473. The upper armature of key 484 transfers the conductor which connects to the armature of relay 419 from the middle left armature of relay 431 to ground over the upper outer contact of the key. As the armature of relay 419 now contacts the left contact of the relay in response to the excessive signal distortion, lamp 485 lights from the ground on the armature of relay 419. The arm of potentiometer 436 is now moved from its zero position toward the left portion of the potentiometer, thereby increasing the normal negative potential on the grid of tube 470. When the adjustment of potentiometer 436 is such that the negative potential on the grid of the tube 470 is increased to a value where the circuit which includes tube 470 does not oscillate on the longest interval during which the short circuit on resistance 468 and condenser 469 is opened by the operations of relays 417 and 418, relay 419 will no longer respond to the excessive distortion and lamp 485 will therefore be extinguished as an indication that the maximum distortion has been reached. Potentiometer 436 may be provided with an indicator calibrated to show the approximate percentage of signal distortion measured in the foregoing manner.

At the conclusion of the measurement, key 484 is restored to its normal position. The restoring of key 484 opens the circuit to lamp 485, removes the ground from the armature of relay 419 and closes the circuit from that armature to the middle left armature of relay 431, and closes the circuit from the left contact of relay 419 through the normally closed inner upper contacts of key 484, to the winding of relay 420. Key 473 is now momentarily operated which opens the locking circuit for relay 420. Relay 420 releases and removes the battery from conductor 214' and conductor 214 of Fig. 2 which silences the audible alarm and extinguishes the visual signal of Fig. 2. The momentary operation of key 473 also connects a ground to conductor 213' and conductor 213 of Fig. 2 to cause the circuits of Fig. 2 to function as previously set forth and connect the succeeding transmission line to conductor 209.

Since the regenerative repeater circuits of Figs. 3 and 4 function under control of the middle portion of each signal impulse, it is obvious that these repeater circuits cannot reproduce incoming signals on which the distortion is so great that the changes in potential polarity on the distributor receiving rings 322 and 422, under the respective control of the operations of relays 302 and 402 in response to the incoming signal impulses, occur after the receiving brushes 313 and 413 have passed the active receiving segments 341 to 346, and 441 to 446 inclusive, respectively. As the receiving brush 313 or 413 passes over its associated active receiving segments, relay 318 or 418, as the case may be, will operate in response to the polarity conditions existing on these receiving segments. These polarity conditions depend upon the positions in which relays 309 and 310 or relays 409 and 410 respectively, were locked to during the preceding operation of the regenerative repeater. The operations of relay 318 or 418 will, therefore, be completely out of synchronism with the operation of relay 317 or 417, respectively.

For the purposes of this specification a regenerative repeater is a device which is actuated by received signals distorted in transmission and produces therefrom signals approximating within the limits of apparatus variations the signals originally transmitted from the originating point of the signals.

When the aforementioned condition of extreme distortion is obtained, an excessive distortion alarm and indicating signal will be given in the manner hereinbefore set forth, but no maximum distortion measurement can be made since any change in the adjustment of condenser 369 of Fig. 3 or in the adjustment of potentiometer 436 of Fig. 4 is ineffective for that purpose due to the fact that relay 318, or relay 418, while operating, is entirely out of control of the incoming impulses.

What is claimed is:

1. A signal distortion measuring device comprising electromagnetic means responsive to periodic signals of marking and spacing character, a regenerative repeater circuit and a delay circuit connected in parallel to said means, and measuring means connected in common to said circuits whereby the outputs of said circuits are impressed on said measuring means to measure difference in phase each time the line signal changes from marking to spacing and vice versa.

2. In combination, a source of periodic marking and spacing signals, a signal distortion measuring device comprising electromagnetic means, a regenerative repeater circuit including rotary start-stop means, a delay circuit including means for delaying the received signals sufficiently to match the lag of the regenerative repeater circuit, and measuring means connected in common to said circuits whereby the outputs of said circuits are impressed on said measuring means to measure their difference in phase each time the line signal changes from marking to spacing and vice versa.

3. A signal distortion measuring device according to claim 1, wherein the delay circuit comprises a continuously operating means for selecting the interval during which the signal distortion measurements are made, and means operative when the distortion exceeds a predetermined amount for rendering the said continuously operated means ineffective.

4. In a signaling system comprising a station, a plurality of signal transmission circuits arranged in groups and terminating at said station,

a signal distortion indicating and measuring device including a continuously rotating timing element, switching means controlled by said timing element for selecting, first, said groups separately and in sequence and, secondly, the circuits of each of said groups separately and in sequence for testing purposes, receiving relay means responsive to the signals received from each of said circuits, parallel paths connected to said receiving relay means, a regenerative repeater circuit and a delay circuit respectively connected in said paths, a plurality of relays synchronously operable when no distortion is present in the received signals, but asynchronously operable when distortion is present, connected in common to said paths and respectively responsive to said repeater circuit and said delay circuit, an operable element controlled by said plurality of relays and arranged to be maintained non-operated at times when no excessive distortion is present in the signals received over each of said plurality of circuits but operated when excessive distortion is present in the signals received over each of said plurality of circuits, and indicating means responsive to said element in an operated condition for determining the circuit over which excessively distorted signals are being received.

5. In a signaling system according to claim 4 wherein the signal distortion indicating and measuring device also comprises locking means for automatically maintaining the selecting, or switching, means stationary in an operated position when excessive distortion is present in the signals received over the circuit being tested, to thereby maintain the indicating means operated and manually operated switching means for releasing said locking means when desired to advance said selecting, or switching means.

6. In a signaling system according to claim 4 wherein the signal distortion indicating and measuring device also comprises quantitative means for indicating the amount of distortion present in the signals received over each of said plurality of circuits.

7. In a signaling system according to claim 4 wherein the signal distortion indicating and measuring device also comprises a rotary stepping device for causing said regenerative repeater circuit to properly receive the signals received over each of said circuits.

8. A signal distortion measuring device comprising a plurality of circuits arranged in groups for transmitting polar signals, a continuously rotating timing cam, switching means controlled by said timing cam for selecting said groups separately and in sequence and said circuits in each group separately and in sequence only at such times when there is no distortion present in signals received over said circuits, a relay responsive to polar signals received over said circuits, a regenerative repeater circuit and a delay circuit connected in parallel to said relay, distortion measuring means connected in common to said repeater and said delay circuit for measuring any difference in duration of corresponding impulses in the output of said repeater and said delay circuit, a pair of relays included in said measuring means respectively responsive to the output of said repeater and said delay circuit and arranged to operate simultaneously at times only when the signals incoming over said transmission circuit

are distortionless, another relay arranged to be maintained in one position by the simultaneous operation of said pair of relays, and an impedance element connected to one of said pair of relays and said other relay for delaying the operation of said other relay for a predetermined interval after either one of said pair of relays release.

9. In a signaling system, a device for measuring distortion present in incoming signals comprising a source of signaling current impulses, relaying means for regenerating said impulses, a circuit for transmitting said regenerated impulses, parallel paths including said circuit, distributing means connected in one of said paths for reproducing the current impulses as originally transmitted from said source, distortion introducing means in another of said paths for delaying the transmission of said regenerated impulses for a predetermined interval, and indicating means common to said parallel paths for indicating and measuring the difference in time between each of said regenerated impulses and its corresponding reproduced impulse.

10. In a signaling system, a device according to claim 9, wherein the distortion introducing means includes a network and an arrangement of electromagnetic relays cooperating therewith to bring a variable element of said network to a steady state between said regenerated impulses.

11. In a signaling system, a device according to claim 9, wherein the distortion introducing means includes two interconnected impedance elements, another impedance element connected to a point between said interconnected elements, a source of potential for maintaining between said regenerated impulses a steady potential of either polarity on said other element, relaying means responsive to the signaling impulses from said source for slowly reversing the polarity of the potential on said other element, other relaying means effective to operate and repeat a signal impulse each time the potential is reduced to zero value, a pair of electromagnetic relays oppositely polarized and responsive to said repeated impulses of opposite polarities, respectively, for expediting the increase of potential of either polarity to its maximum value on said other impedance element.

12. A device for measuring distortion of signal impulses incoming over a plurality of transmission lines arranged in groups, comprising electromagnetic means responsive to periodic signal impulses incoming over said lines, a selective mechanism for automatically connecting in a regular sequence each of said lines to said electromagnetic means, a regenerative repeater circuit including rotary start-stop means, a delay circuit including means for delaying the incoming signal impulses sufficiently to match the lag of the signal impulses repeated by said regenerative circuit, measuring means connected in common to said circuits whereby the outputs of said circuits are impressed on said measuring means to measure the difference in phase of the beginning and ending of corresponding signal impulses, indicating means, and other selective mechanism operated simultaneously with the first mentioned selective mechanism for operating said indicating means each time a difference in phase occurs in corresponding signal impulses.

FULLERTON S. KINKEAD.