

Aug. 11, 1931.

A. M. CURTIS ET AL

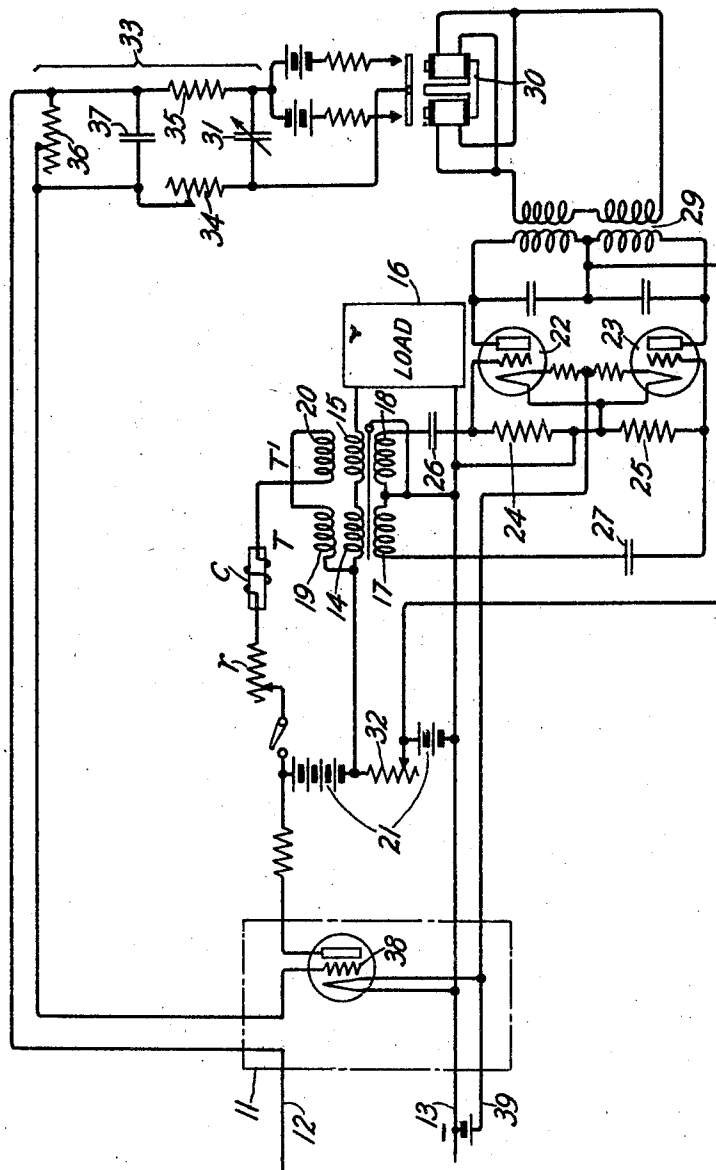
1,818,463

ZERO CORRECTING CIRCUIT

Filed Sept. 15, 1928

4 Sheets-Sheet 1

FIG. 1.



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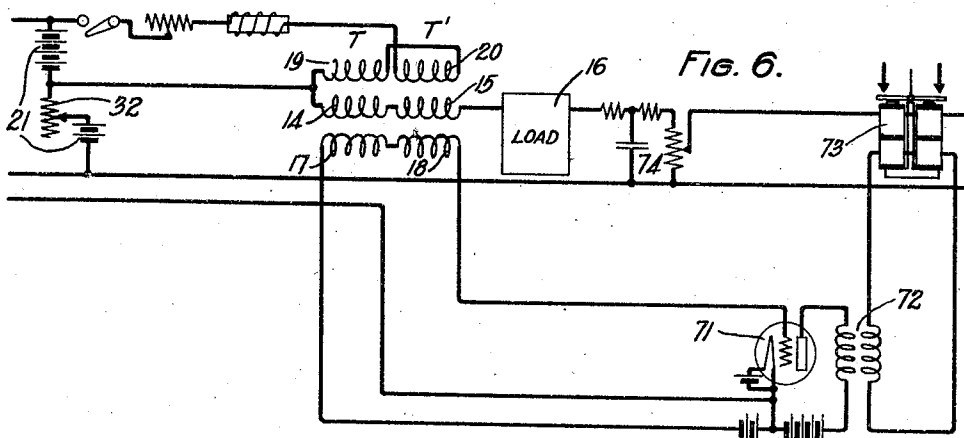
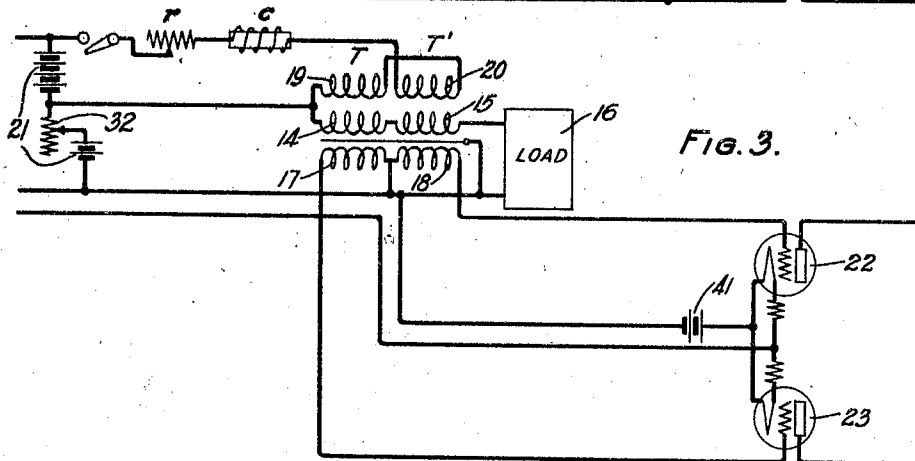
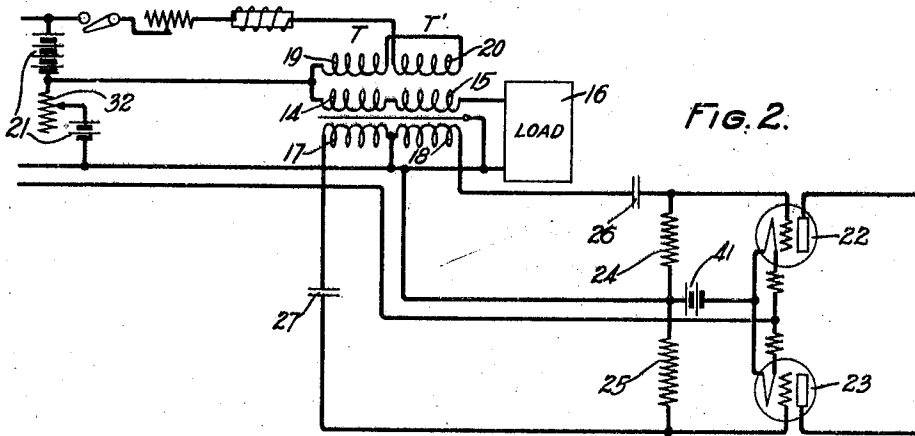
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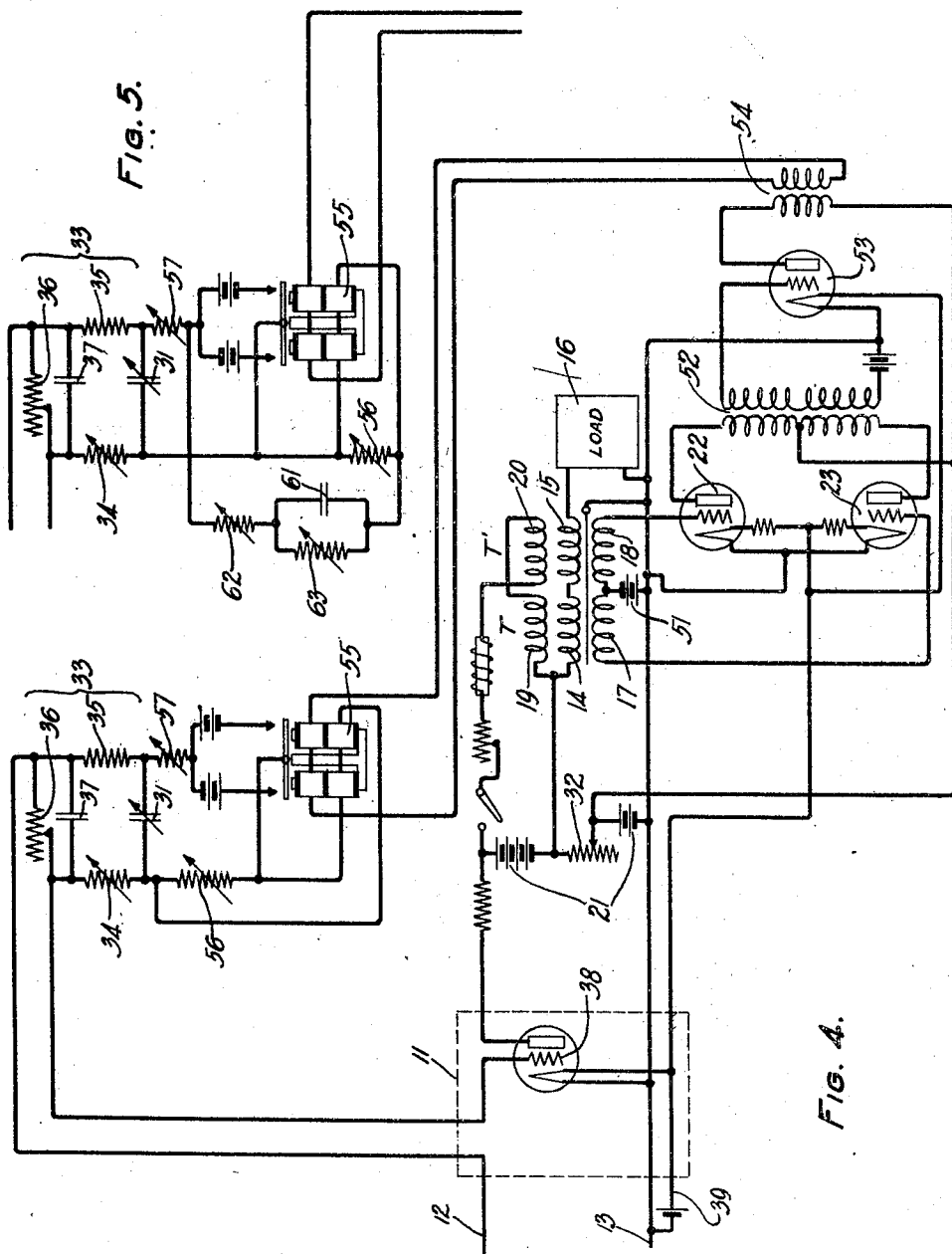
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4 Sheets-Sheet 3



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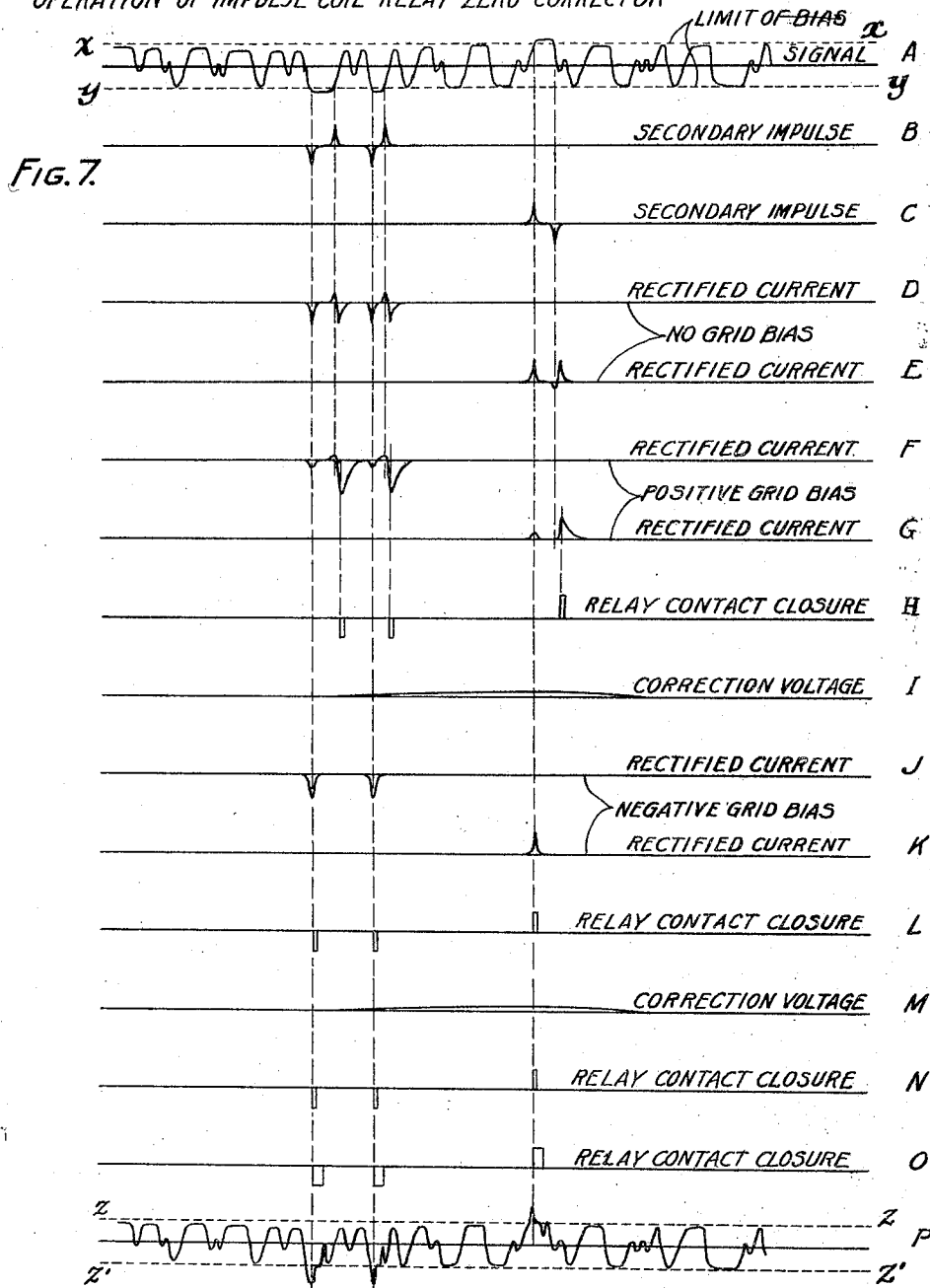
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ZERO CORRECTING CIRCUIT

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4 Sheets-Sheet 4

OPERATION OF IMPULSE COIL-RELAY ZERO CORRECTOR



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ZERO CORRECTING CIRCUIT

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This invention relates to signaling systems and particularly to receiving systems for use in connection with submarine cables.

An object of the invention is to correct for the effect known as zero wander in a highly efficacious manner.

A feature of the invention is the use of high permeability inductance coils for effecting the operation of a correcting relay in a positive manner.

It is well known in the art that in signaling over high capacity cables by means of positive and negative impulses, earth currents or a temporary preponderance of impulses of one polarity will cause an accumulative charging effect on the cable which manifests itself as an apparent shifting of the zero line of the signal wave. This is commonly known as zero wander and may be corrected by various methods. One method is that used in the New York-Azores submarine cable system and disclosed in U. S. Patent No. 1,675,096, granted to A. M. Curtis on June 26, 1928, wherein a correcting relay is operated directly by incoming signals every time the signal current, due to the addition thereto of earth currents or the low frequency currents caused by "zero wander", exceeds its normal peak value. The operation of the relay is caused to produce low frequency current surges which are superimposed on the incoming signals in such manner as to restore the zero of the signal current to its true position. Another method consists in passing a signal current through the primary windings of a pair of transformers having cores of a magnetic material of high permeability, the cores being magnetized in opposite directions, by direct currents, whereby the mutual inductance of the windings is maintained at a negligible value until the primary current exceeds its normal peak value, at which time the mutual inductance rises to a high value for an instant to produce in one of the transformer

secondary windings a short pulse of voltage which after passing through a rectifier and charging a condenser is superimposed on the incoming signals in the form of a surge of low frequency and long duration, to restore the zero of the signaling current to its true position.

In the method in accordance with Patent 1,675,096 the relay is adjusted in such a manner that the contacts do not touch each other unless the zero of the signal, by deviation from its normal position, causes the peak value of the signal to exceed its usual value for one polarity, and while this method is successful its correct operation depends upon precise maintenance of the adjustment of the relay. Owing to the fact that the operation of the system depends, at times, upon the relay just barely making contact the operation is less positive than is desirable. Burton's method wherein the transformers are used to produce the corrective impulses directly, is rather more complex than desirable.

The present invention combines the advantageous features of both the prior methods and effects an improvement over both of the above methods by employing the high permeability transformers to produce sharp, discrete secondary impulses every time the signal current exceeds its normal peak value, by passing the secondary impulses through a pair of rectifiers arranged in push-pull relation, and by utilizing the rectified impulses to operate a relay. In this arrangement the necessity for practically perfect adjustment of the relay is eliminated and the correcting impulses, which are produced by the relay, are of sufficient strength to quickly restore the zero of the signal current to its true position.

A further feature of the present invention is the utilization of an amplifier inductively connected to the output circuits of the recti-

fiers whereby the rectified impulses are increased in strength.

A still further feature is the use of a locking circuit in conjunction with the corrector relay, which holds the relay contacts in engagement for a variable length of time after a short impulse of operating current has passed through its winding.

Another feature is the method of controlling the secondary impulses whereby certain impulses are suppressed and other impulses are inverted and increased in strength.

Another feature is the arrangement of a multistage vacuum tube amplifier, a pair of vacuum tube rectifiers and a second vacuum tube amplifier wherein common sources of current are furnished for both the filament and plate circuits of the amplifiers and rectifiers.

Another feature is the utilization of some of the signaling current in one winding of the corrector relay to aid amplified impulses in the operation of the relay when zero wander occurs on the signal.

The invention will be described in connection with the accompanying drawings in which:

Fig. 1 illustrates a preferred embodiment in connection with a submarine cable terminal.

Fig. 2 is a modification of Fig. 1 wherein a "C" battery is employed in the grid circuit of the rectifiers for the purpose of maintaining the grids normally positive with respect to their associated filaments.

Fig. 3 is a modification of Fig. 2 wherein the grids are made normally negative with respect to their associated filaments by a potential which reduces the space current of the tubes to a low value except when a positive pulse is applied to the grid.

Fig. 4 is a modification of Fig. 1 wherein an amplifier is inductively connected to the output circuits of the rectifiers and a locking circuit is employed in conjunction with the corrector relay for holding the relay contacts in engagement for a variable length of time.

Fig. 5 is a modification of Fig. 4 wherein a shunted condenser is employed in the locking circuit of the corrector relay for regulating the duration of operation of the relay.

Fig. 6 is another modification of Fig. 1 wherein the signaling current itself is utilized in aiding the operation of the corrector relay.

Fig. 7 is a series of curves giving a graphic representation of the operation of the circuit arrangements shown herein.

Like parts are designated by like numbers.

Referring to Fig. 1 a multi-stage vacuum tube amplifier 11 connects a signaling line comprising conductors 12 and 13, through

the primary windings 14 and 15 of a pair of high permeability transformers T and T' to a receiving circuit 16. The transformers are referred to herein as impulse coils. These transformers or impulse coils are equipped with cores which are designed to become magnetically saturated at the low amplitudes of the signaling current flowing through the primary windings. In the absence of any direct polarizing current being applied to the transformers either through separate windings or through the primary windings, the inductance of the primary windings during intervals in which the signaling current is rising through very low amplitudes, would be caused to rise momentarily to a high value thereby producing in either of the secondary windings 17 and 18 a short, sharp voltage impulse, the winding selected for the secondary impulse being determined by the polarity of the signaling current at the time. In the event that a direct polarizing current is applied to the impulse coils, either through the primary windings or separate windings mounted thereon, the cores may be polarized over the range of low amplitudes, and therefore the active intervals during which the secondary impulses occur, may be shifted to include a range of the higher amplitudes.

In the embodiment of this invention shown in Fig. 1, separate windings 19 and 20 are wound on impulse coils T and T' respectively, and direct current is sent through them to keep the cores magnetically saturated. A resistance r and a choke coil c are included in the circuit of windings 19 and 20 to prevent them from absorbing an appreciable amount of power from the primary windings. The direction of current flow in the magnetizing windings is chosen so that the cores are polarized in opposite directions with respect to the direction of flow of the signal current. The cores, or that part of the cores associated with the primary or the secondary winding, are thus maintained of a negligible permeability, and the transformers are accordingly inactive through lack of appreciable mutual inductance, during all times except those in which the magnetomotive force produced by the signal current is of the opposite polarity, and equal or nearly equal to the magneto-motive force produced by the polarizing current. Only during such periods the transformer becomes active and produces in its secondary winding pulses of one polarity when the signal magneto-motive force rises through the range of the magneto-motive due to the polarizing current, and of the opposite polarity when the signal current falls through this range.

Assuming that a signaling current wave flowing in the output circuit of amplifier 11 and primary windings 14 and 15 is distorted,

by the addition of a component of very low frequency and manifests itself as shown by curve A of Fig. 7 wherein the apparent shifting of the zero axis of the signal wave is first in a negative direction and later, due to an exaggerated operation of the corrector circuit, is in a positive direction, the biasing or polarizing current is given such value as to maintain the impulse coil cores saturated until the signaling current rises to its normal peak positive and negative values. These values are respectively indicated in Fig. 7 by broken lines $x-x$ and $y-y$ and every time the signaling current passes through these values an impulse is produced in either of the secondary windings 17 and 18. For the sake of illustration it is assumed that an impulse is produced in secondary winding 17 when the excessive signaling current is positive and in secondary winding 18 when the excessive signaling current is negative. Therefore according to curve A an impulse is produced in winding 17 every time the trace of curve A rises above line $x-x$ and in winding 18 every time trace a falls below line $y-y$. As the signaling current of positive polarity continues to rise and attains an amplitude slightly above its normal peak value, the core of the impulse coil T becomes resaturated and the inductance again becomes negligible and remains so as long as the core is saturated, but as soon as the current drops to a value at which the core of coil T becomes unsaturated, the inductance of the primary winding 14 again rises for an instant to a high value to produce a second impulse in winding 17. Two impulses will also be produced in winding 18 every time the signaling current drops and exceeds its normal peak negative value. This is illustrated in curves B and C of Fig. 7, curve B representing the secondary impulses produced in winding 18 and curve C the secondary impulses produced in winding 17.

In one example of this circuit, shown in Fig. 1, the secondary windings 17 and 18 are connected to a pair of vacuum tube rectifiers 22 and 23 which are respectively provided with grid leaks 24 and 25 and grid condensers 26 and 27. The plate circuits of the vacuum tube rectifiers are connected through a transformer 29 to the windings of a corrector relay 30, and are furnished with current from source 21. The filaments receive their current supply over conductors 39 and 13 from the filament battery of amplifier 11.

The impulse coils are connected to the amplifier and to the rectifiers in such a direction that if a secondary impulse is produced in either of windings 17 and 18 by the signal, rising in amplitude from zero to a maximum positive or negative value which exceeds that for which the biasing

current is adjusted, the secondary impulse carries the grid of one of the rectifiers 22 and 23 negative, whereby the impulse is subjected to direct amplification. When a secondary impulse occurs during a falling signaling amplitude the voltage applied to the grid circuit is positive and electrons are attracted to the grid and accumulate thereon more rapidly than they can be dissipated through the grid leak resistance 24 or 25. As a result the grid condenser associated with the winding in which the secondary impulse occurs, becomes charged to a rather high negative value, which charge, at the termination of the impulse, causes a large drop in plate current the duration and magnitude of which is governed by the size of the condenser and the grid leak resistance 24 or 25. This plate current surge, after passing through transformer 29 is employed to cause the armature of relay 30 to touch one of its associated contacts and to hold it in this position sufficiently long to charge storing condenser 31 of a filter such as described in Curtis Patent No. 1,675,096, supra. The vacuum tube rectifiers are arranged in push-pull relation as shown in the drawings and consequently impulses of like polarity respectively produced in the windings 17 and 18 cause impulses in the plate circuits of the rectifiers to be opposite in phase.

An illustration of the plate current impulses caused by the impulses produced in secondary windings 17 and 18 is given in curves D and E of Fig. 7. Relay 30 which is preferably of the type disclosed in Curtis Patent No. 1,675,096 supra, is adjusted to respond to the larger plate current impulses and therefore reproduces these impulses by applying a voltage to a resistance-capacity network 33 during the time of contact indicated in curve H of Fig. 7. The voltage impulses are each in turn impressed on storing condenser 31 and the charge flows to condenser 37 through the resistance-capacity network 33 which comprises resistance elements 34, 35 and condenser 37. This charge can leak off through resistance 36. The apparatus is connected so that the charge applied to grid 38 by condenser 37 is of such a polarity as to oppose and of such magnitude as to neutralize the original displacement of the average grid potential which caused the impulse coil to operate, and consequently restores the grid potential to its normal value. The potentials impressed on grid 38 of the amplifier 11 are shown in curve I of Fig. 7.

The arrangement of the rectifiers shown in Fig. 1 may be modified to include a "C" battery in the circuit of the grids whereby either a positive or negative potential may be normally impressed upon the grids or an effective positive grid potential may be obtained by connecting the filament connec-

tion of the grid-filament current to the positive end of the filament, as is well known in the art.

Referring to Fig. 2 the grids of rectifiers 22 and 23 are each connected to the positive pole of a "C" battery 41 through leak resistances 24 and 25 whereby the grids are normally maintained at a positive potential with respect to their associated filaments. Assuming that the signaling current flowing in primary windings 14 and 15 of Fig. 2 is of the same wave form as curve A of Fig. 7 the impulses produced in the secondary windings 17 and 18 when the signaling current exceeds its normal peak values will likewise be the same. The resulting rectified current impulses produced by the circuit arrangement of Fig. 2 are represented in Fig. 7 by curves F and G which correspond respectively to curves D and E. As the positive grid potential produces a conductive path between grid and filament, and markedly reduces the impedance between them the impulse originating in either of the secondary windings during rising signaling amplitude renders the grid of the rectifier connected to the particular winding considerably less negative than when the grid is normally at zero potential as shown in Fig. 1. The resulting plate current impulse is thereby reduced to a negligible value. On the other hand, the positive grid potential improves the efficiency of the tube as a rectifier, and while it operates substantially as described above with reference to Fig. 1, the rectified pulse produced when the magneto-motive force generated by the signal current falls through the range of that due to the biasing current is somewhat larger than is the case when the circuit of Fig. 1 is used. As an effective operating impulse is produced only once in a half cycle of the signaling current the adjustment of the relay is somewhat simplified.

Should it be desired to apply the corrector impulses during the rising signal amplitudes only, a circuit arrangement such as shown in Fig. 3 may be employed.

In the arrangement of Fig. 3, the grid leak resistances 24 and 25 and grid condensers 26 and 27 shown in Figs. 1 and 2, are omitted and the negative pole of a "C" battery 41 is connected to the grids of rectifiers 22 and 23 as shown. The "C" potential is chosen with reference to the plate potential and the tube characteristics so that the normal plate current is nearly or quite suppressed. The secondary windings of the impulse coils are connected to the rectifiers in such a sense that an impulse originating in either of the secondary windings during rising signaling amplitude applies a positive potential to the grid of the rectifier associated with that winding which causes a

large increase in the plate current. The secondary impulse occurring during the falling signal amplitude applies a negative voltage to the grid, which can only have the effect of reducing to zero the already negligible plate current. By increasing the normal negative grid potential the plate current surges resulting from the secondary impulses occurring on the falling signaling amplitudes may be entirely eliminated. In Fig. 7 curves J and K represent the resulting plate current impulses which are produced by rectifiers 22 and 23 respectively and are effective to operate the corrector relay, thereby producing correcting impulses during the time of contact as shown in curve L. The corresponding potentials impressed on grid 38 (Fig. 1) are shown in curve M.

A modification of Fig. 3 is shown in Fig. 4 wherein the correcting relay is operated by an impulse produced on the rising signal amplitude. Of the circuit arrangements shown herein, this arrangement is the most desirable for submarine cable transmission. The simple negative grid type of rectifier shown in Fig. 3 produces the impulse at the front of the signal, or in other words, during the rising signal amplitude, but this impulse is of a strength which requires a rather sensitively adjusted relay and the contact is of so short a duration that the flexibility of adjustment of the correcting network 33 is somewhat restricted. Therefore in order to increase the ease of adjustments the circuit arrangement of Fig. 4 provides an amplifier which is inductively connected to the output circuits of the rectifier for increasing the strength of the impulses. Furthermore, there is included in the contact circuit of the correcting relay an additional feature which locks the relay contacts in an operated position for a variable length of time, depending on the past history of the circuit, in such a way as to allow the relay to operate on a very short impulse and to charge a storing condenser to any level to which it is desired to adjust the circuit. Referring to Fig. 4 the impulses are produced in the secondary windings 17 and 18 of impulse coils T and T' in the same manner as described above for the arrangement shown in Fig. 1. The secondary windings are respectively connected to rectifiers 22 and 23 which are arranged in push-pull relation. A "C" battery 51 provides for rectifiers 22 and 23 a negative grid potential sufficiently high to prevent an appreciable amount of plate current flowing except when the secondary impulse of positive polarity is applied to either of the grids. The output circuits of the rectifiers are connected through transformer 52 to an amplifier 53. This amplifier serves to increase the strength of the rectified current impulses which are

sent through transformer 54 to a corrector relay 55. It is understood, of course, that amplifier 53 may be omitted in cases where the design of the impulse coils permits the operating value of the secondary impulses to be increased. Relay 55, like relay 30 shown in Fig. 1, is of the polarized type and comprises two pairs of windings, the upper pair serving to operate the relay and the lower pair for maintaining the relay operated for intervals of variable duration after the operating impulses have terminated. Relay 55 in responding to an impulse received from the output coil of transformer 54 closes either of its contact circuits, depending upon the polarity of the received impulse, and therefore impresses on storing condenser 31 a charge of corresponding polarity. In order that this charge may attain a level to which it is desired to adjust the circuit, two adjustable resistances 56 and 57 are inserted in series with condenser 31 and the voltage drop across resistance 56 is fed back through the lower or locking windings of relay 55 in a direction which causes the relay armature to be held operated in the same direction as that in which it was operated by the impulse which originally caused condenser 31 to start charging. In other words, if the condenser is uncharged, the relay armature will be held in contact by the signal impulse for only a very short time but will immediately be locked up by the current charging the condenser 31 until the latter has decreased to a certain value set by the battery voltage, resistances 56 and 57 and the sensitivity of the relay. If condenser 31 is already charged, due to a succession of impulses in the same direction, the locking windings will, of course, have no effect. If the condenser 31 is fully charged and the operating windings receive an impulse which causes the relay armature to move to its opposite contact, the voltage applied to the locking winding will be doubled and the length of the contact time increased.

A modification of the relay locking circuit which permits the duration of the locking effect to be adjusted independently of the zero correcting filter network is shown in Fig. 5. Here an additional condenser 61 and resistance 62 may be employed, condenser 61 being shunted by a leak resistance 63, whereby the locking effect due to the impulse charging condenser 61, is reduced to the effect produced by the current passing through resistance 63 in a definite time set by the relation of the capacity to the resistance. Condenser 61 and resistance 63 are chosen of such values that the condenser may be completely discharged in the interval ordinarily elapsing between operations of the relay armature from the positive to its negative contacts, and vice versa, with the circuit operating in normal condition. These

intervals may ordinarily be of the order of half a second. Curve N of Fig. 7 represents the impulses produced by relay 55 in the circuit arrangements of Figs. 4 and 5 when the secondary impulses alone are used and curve O shows the impulses increased in duration by means of the locking circuit.

Another modification of Fig. 1 is shown in Fig. 6 wherein the corrector circuit is greatly simplified by replacing the rectifiers by a simple amplifier, the necessary correction being effectively accomplished by passing a portion of the signaling current through separate windings on the corrector relay. Referring to Fig. 6 the impulse coils T and T' have their secondary windings 17 and 18 connected in series to a vacuum tube amplifier 71. The amplifier output circuit is inductively connected through transformer 72 to a corrector relay 73. This corrector relay is equipped with two pairs of windings, the lower pair being connected to the transformer 72. The primary windings 14 and 15 of impulse coils T and T' are connected through the load circuit 16 to the upper pair of windings of relay 73, so that the signaling current which passes through the primary windings is received by relay, connected across the circuit extending through the upper windings of relay is a network 74 which comprises a potentiometer for varying the amplitude of signaling current passing through the relay windings and a combination of impedance elements for preventing voltages induced from the lower windings of the relay from passing back into the primary circuit of the impulse coils.

Curves A, B, C and P graphically show the operation of the circuit arrangement shown in Fig. 6. Curve A shows the wandering signal wave passing through the primary windings 14 and 15 of impulse coils T and T', curves B and C show the resulting voltages in the secondary windings 17 and 18, and curve P shows the wave form of the magnetic flux produced by the addition of the magnetic fluxes produced by the signaling and secondary voltages flowing through the relay windings. Corrector relay 73 is designed to operate only when the magnetic flux wave in curve P exceeds the amplitudes indicated by the broken lines Z and Z'. It will be noted that the relay is operated only when the signaling and impulse currents are of the same polarity. With this circuit therefore it is possible to operate the relay either on the rise or the fall of the excessive signaling current by properly poling the secondary windings of impulse coils T and T'. In addition to eliminating the rectifiers and substituting therefor a single amplifier this form of zero corrector provides for a considerable reduction in the amplitude of the impulse current required for the operation of the corrector relay.

Comparative freedom from maintenance is assured in using this system since the impulse coils never require adjustment and the corrector relay needs no accurate adjustment. The biasing current passes through two coils in series, as shown in Fig. 1, and therefore no unbalance of the corrector will occur. Contact trouble with this circuit should be negligible since the rectified impulses are sufficient to operate the relay very positively.

The sensitivity of applicant's zero corrector may be estimated from the observation that with normal adjustment of the circuits a variation in the zero of the signaling current of about .3 milliamperes in a signal having a peak value of 10 milliamperes is sufficient to cause the correcting relay to receive operating pulses of maximum strength.

It is, of course, understood that devices in accordance with the principles of the invention as expressed in the appended claims may be employed in connection with other signaling systems than those herein described.

What is claimed is:

1. A wave amplifying system comprising an amplifier proper such as a thermionic amplifier, impulse coil means comprising primary and secondary windings connected in the output circuit thereof functioning to produce in the secondary windings impulses of current only as the amplified waves have maxima exceeding a predetermined value, and relay mechanism operated by the impulses produced in said secondary windings.

2. A system in accordance with claim 1, wherein means for correcting wandering zero in an incoming signaling wave is had by connecting in the input circuit of the amplifier other circuits comprising networks, a local source of current, and the armature and contacts of the relay mechanism, one or the other of said other circuits being arranged to close whenever the amplified waves attain amplitudes above a predetermined value and to superimpose on the input voltage, a voltage of such a polarity as to oppose and of such magnitude as to neutralize the original displacement of the true zero of the incoming signal wave.

3. A system in accordance with claim 1 characterized by the provision of individual impulse coils operating on excessive positive and negative waves, respectively, and individual rectifiers between the impulse coils and the relay mechanism to permit the passage of a pulse of only the desired polarity.

4. A system in accordance with claim 1, characterized by the provision of individual impulse coils operating on excessive positive and negative waves respectively, individual rectifiers between the impulse coils and the relay mechanism to permit the passage of pulses of only the desired polarity by in-

creasing the magnitude of certain of said impulses and suppressing the other of said impulses.

5. A system in accordance with claim 1, characterized by the provision of individual impulse coils operating on excessive positive and negative waves respectively, individual vacuum tube rectifiers between the impulse coils and the relay mechanism to permit the passage of pulses of only the desired polarity, each of said rectifiers comprising a grid circuit, and means in said grid circuits for increasing the magnitude of certain of said pulses and decreasing the magnitude of the other of said pulses through said relay mechanism.

6. A system in accordance with claim 1, characterized by the provision of individual impulse coils operating on excessive positive and negative waves respectively, individual rectifiers between the impulse coils, each of said rectifiers comprising a grid element and the relay mechanism to permit the passage of pulses of only the desired polarity by regulating the normal grid potentials of said rectifiers to control both the position, with respect to the rising and falling amplitudes of the amplified waves, and the amplitude of said rectified current.

7. A system in accordance with claim 1, characterized by the provision of a second device for amplifying the impulses produced when a maxima of the first amplified waves exceed a predetermined value, to satisfactorily operate the relay mechanism.

8. A system in accordance with claim 1, characterized by the provision of additional means for maintaining said relay mechanism in an operated position sufficiently long to restore the amplitude of the amplified waves to a predetermined value.

9. A system in accordance with claim 1, characterized by the provision of a lock-up circuit to hold the relay mechanism in operated position for a time independent of the nature of the impulse which caused its operation.

10. In a zero corrector circuit comprising a pair of transformers polarized in opposite directions, a pair of rectifiers respectively connected to said transformers, a polar electromagnetic device and a network, a method of restoring the zero axis of a signal wave to its true position which consists in producing secondary impulses of opposite polarities when and only when the signal wave amplitude exceeds its normal peak value, rectifying the secondary pulses over one of two paths so that impulses of one polarity only are transmitted as a result of the current exceeding its peak value in one direction only, reproducing and shaping said transmitted rectified impulses as a series of low frequency surges, and impressing said surges on the signal wave so as to neu-

tralize that portion of the signaling current which caused the displacement of the zero axis.

11. In an electrical signaling circuit, a source of signaling current, a pair of high permeability transformers comprising cores each having mounted thereon primary and secondary windings, said cores being polarized to such an extent that their permeability is reduced to a negligible value except at such times as the signaling current in the primary windings passes through values of current which reduce said polarizing magneto-motive force to a value which permits the normal permeability of the cores to be developed, a device having unilateral electrical conductivity associated with the secondary winding of each of said transformers, and a relay circuit associated with said devices and arranged to operate in response to current impulses received from said secondary windings through said devices when the signaling current rises through values at which the normal permeability of the cores is developed.

12. In an electrical signaling circuit, a source of signaling current, a pair of high permeability transformers comprising cores each having mounted thereon primary and secondary windings, said cores being polarized to such an extent that their permeability is reduced to a negligible value except at such times as the signaling current in the primary windings passes through values of current which reduce said polarizing magneto-motive force to a value which permits the normal permeability of the cores to be developed, a device having unilateral electrical conductivity associated with the secondary winding of each of said transformers, and a relay circuit associated with said devices and arranged to operate in response to current impulses received from said secondary windings through said devices when the signaling current falls through values at which the normal permeability of the cores is developed.

13. In an electrical circuit, a source of signaling current, a pair of oppositely polarized transformers each comprising a primary and a secondary winding, the secondary windings being adapted to repeat signal impulses when, and only when the signaling current in said primary windings differs from its predetermined normal character; unidirectional conductor associated with each of said secondary windings, a relay circuit associated with said unidirectional conductors and arranged to operate in response to impulses received therefrom.

14. In an electrical signaling circuit, a source of signaling current, a pair of oppositely polarized transformers each comprising a primary and a secondary winding, the secondary windings being adapted to

repeat signal impulses when and only when signaling current in said primary windings passes through values of current which reduce said polarizing flux of either of said transformers to a value which permits the normal permeability of the particular transformer core to be developed, a device having unilateral electrical conductivity associated with each of said secondary windings, one of said devices arranged to transmit the repeated impulses of one polarity and the other of said devices arranged to transmit the repeated impulses of the other polarity, and an electromagnetic device associated with the first mentioned devices and responsive to the repeated impulses.

15. In an electrical signaling circuit, a source of signaling current, a pair of oppositely polarized transformers, each comprising a primary and a secondary winding, the secondary windings being adapted to repeat signal impulses when and only when the signaling current from said primary windings passes through values of current which reduce said polarizing flux of either of said transformers to a value which permits the normal permeability of the particular transformer core to be developed, a device having unilateral electrical conductivity associated with each of said secondary windings, and a relay associated with said devices and responsive to impulses received therefrom, one of said devices being arranged to transmit to said relay the impulses of one polarity generated in one of said secondary windings when the signaling current rises through its critical value and to reject the impulses of the opposite polarity generated when the signaling current drops through its critical value, and the other of said devices being arranged to transmit to said relay the impulses corresponding in polarity to those rejected by the first of said devices, the impulses transmitted and rejected by the second device being respectively opposite in polarity to the impulses transmitted and rejected by the first device.

16. In a zero correcting circuit, a source of signaling current, a pair of oppositely polarized transformers each comprising primary, secondary and polarizing windings, the secondary windings being adapted to repeat impulses when and only when the signaling current in said primary winding passes through values which reduce said polarizing flux of either of said transformers to a value which permits the normal permeability of the particular transformer core to be developed, a unidirectional conductor connected to each of said secondary windings, said conductors being arranged to transmit the repeated positive impulses and the repeated negative impulses respectively, a polar relay having its armature and contacts normally out of engagement,

a suitable transformer for connecting said relay to said unidirectional conductors, said relay being so connected that the impulse repeated by one of said polarized transformers and transmitted through one of said conductors when the signaling current rises through its critical positive value will cause the relay armature to engage one of its associated contacts, and the impulse repeated by the other of said polarized transformers and transmitted through the other of said conductors when the signaling current rises through its critical negative value will cause the armature to engage the other of its associated contacts, and circuits associated with said contacts arranged to generate a surge of current of a wave form suitable for superimposition on the signaling current.

17. In a zero correcting circuit, a source of signaling current, a pair of positively polarized transformers each comprising primary, secondary and polarizing windings, the secondary windings being adapted to repeat impulses when and only when the signaling current in said primary winding passes through values which reduce said polarizing flux of either of said transformers to a value which permits the normal permeability of the particular transformer core to be developed, a unidirectional conductor connected to each of said secondary windings, said conductors being arranged to transmit the repeated positive impulses and the repeated negative impulses respectively, a polar relay having its armature and contacts normally out of engagement, a suitable transformer for connecting said relay to said unidirectional conductors, said relay being so connected that the impulse repeated by one of said polarized transformers and transmitted through one of said conductors when the signaling current falls through its critical positive value will cause the relay armature to engage one of its associated contacts, and the impulse repeated by the other of said polarized transformers and transmitted to the other of said conductors when the signaling current falls through its critical negative value will cause the armature to engage the other of its associated contacts, and circuits associated with said contacts arranged to generate a surge of current of a wave form suitable for superimposition on the signaling current.

18. In a zero correcting circuit, a source of signaling current, an amplifier, polarized transformers having primary windings connected in the output circuit of said amplifier, and secondary windings arranged to produce voltage impulses of either polarity when the signaling current in the primary windings exceeds its normal peak values, and a signaling device associated with the secondary windings of said transformers for reproducing and impressing impulses corresponding

to those produced in the secondary windings on said amplifier to restore the zero of the signaling current to its true position.

19. In a zero correcting circuit, a source of signaling current, an amplifier, transformers each comprising a primary, a secondary, and a polarizing winding, said transformers having cores oppositely polarized to a flux density equivalent to that caused by the normal peak values of the signaling current flowing through said primary windings, rectifiers respectively connected to said secondary windings, a high speed receiving device, a second amplifier connected to the output circuits of said rectifiers, means connected to said receiving device and responsive to the operation thereof for generating impulses corresponding to those produced by either of said secondary windings every time the signaling current in the primary windings exceeds its normal peak values and for impressing said generated impulses on said amplifier to restore the zero axis of the signaling current to its true position, and a locking circuit in said receiving device for maintaining it operated for intervals of variable duration, independent of the duration of the operating impulses.

20. In a zero correcting circuit, a source of signaling current, an amplifier, transformers each comprising a primary, a secondary, and a polarizing winding, said transformers having cores oppositely polarized to a flux density equivalent to that caused by the normal peak values of the signaling current flowing through said primary windings, amplifying means connected to said secondary windings, a high speed receiving device responsive to the signaling current and the impulses produced in said secondary windings when the signaling current rises through its normal peak positive and negative values, and means connected to said receiving device and responsive to the operation thereof for generating impulses corresponding in polarity to those produced by either of said secondary windings and for impressing said generated impulses on said amplifier to restore the zero axis of the signaling current to its true position.

21. In a zero correcting circuit, a source of signaling current, an amplifier, transformers, each comprising a primary, a secondary, and a polarizing winding, said transformers having cores oppositely polarized to a flux density equivalent to that caused by the normal peak values of the signaling current flowing through said primary windings, amplifying means connected to said secondary windings, a high speed receiving device responsive to the signaling current and the impulses produced in said secondary windings when the signaling current falls through its normal peak positive

and negative values, and means connected to
said receiving device and responsive to the
operation thereof for generating impulses
corresponding in polarity to those produced
5 by either of said secondary windings and for
impressing said generated impulses on said
amplifier to restore the zero axis of the sig-
naling current to its true position.

10 In witness whereof, we hereunto subscribe
our names this 14th day of September, 1928.

AUSTEN M. CURTIS.
EVERETT T. BURTON.

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