April 4, 1939. A. E. BACHELET ET AL 2,153,128

SELECTIVE SIGNALING SYSTEM

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FIG. 1

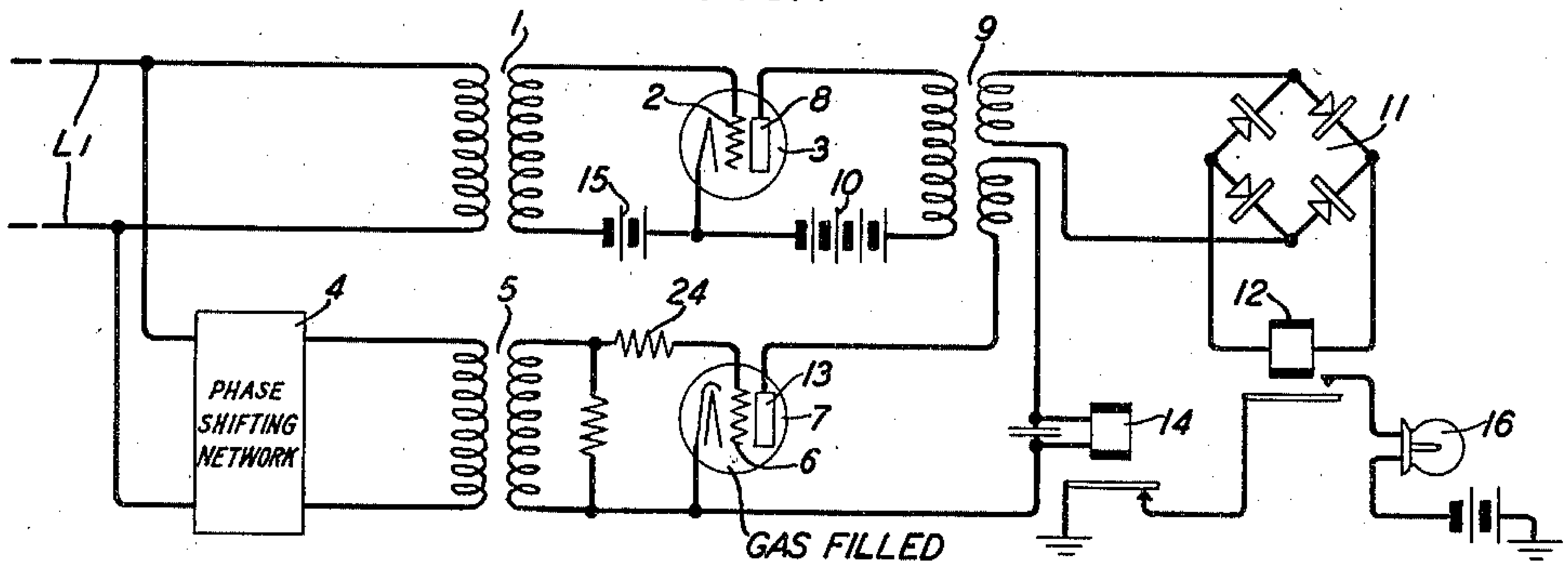


FIG. 2

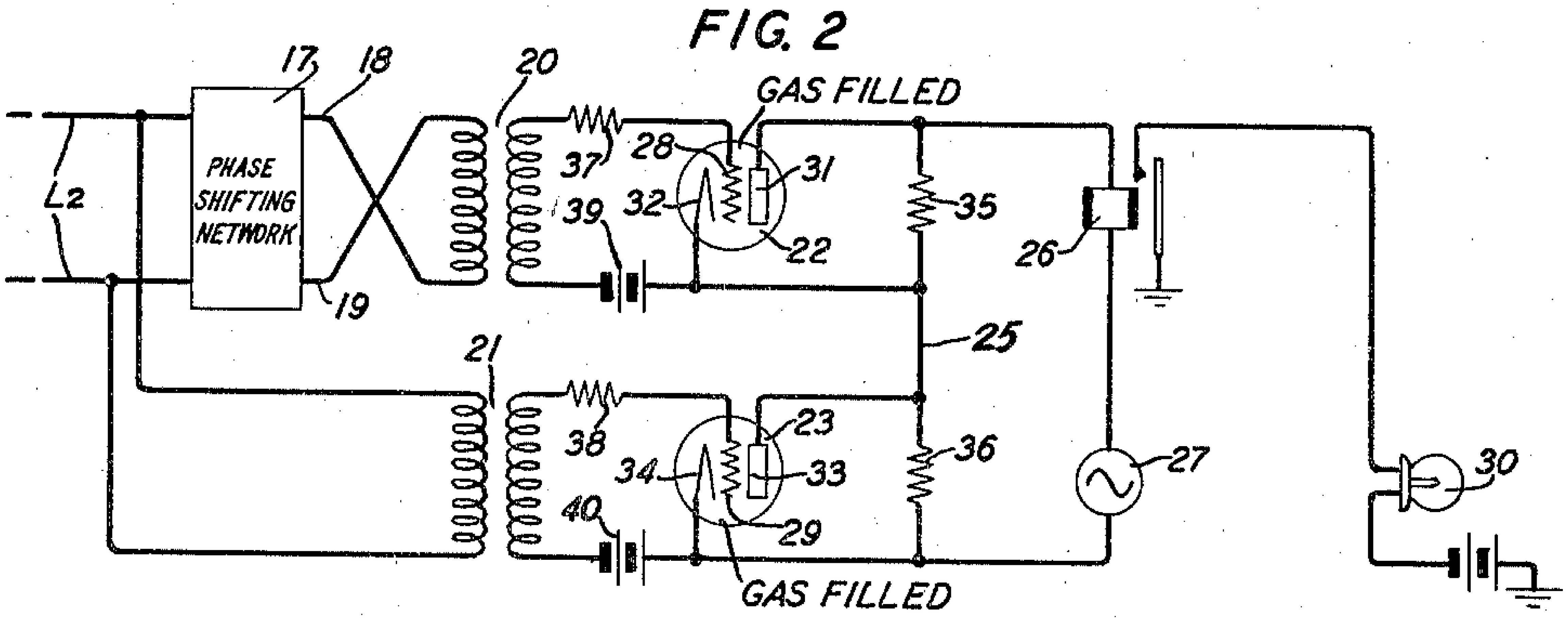
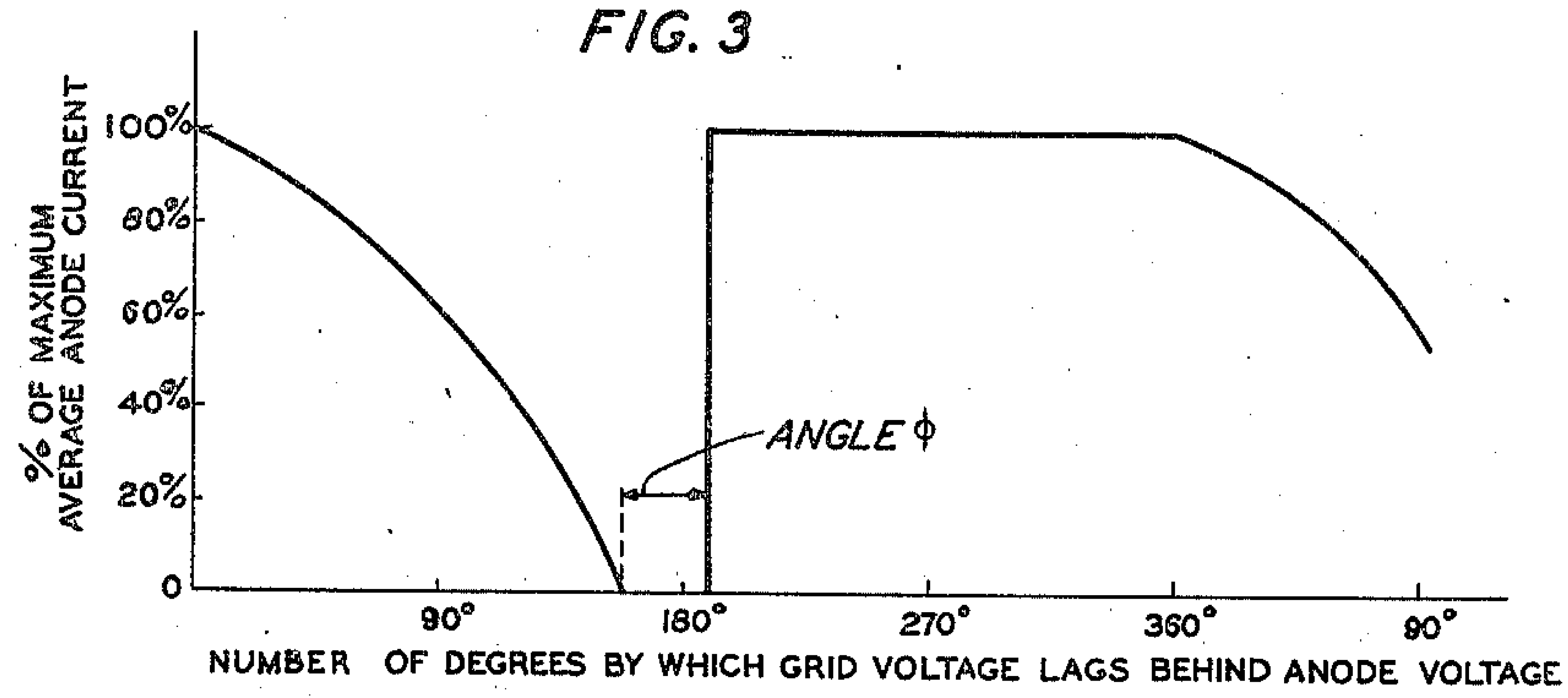


FIG. 3



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SELECTIVE SIGNALING SYSTEM

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5 Claims. (Cl. 179—84)

This invention relates to selective signal receiving circuits.

An object of the invention is to provide an arrangement of the above character which will respond to a single unmodulated frequency and discriminate sharply against all other frequencies.

A feature of the invention whereby the above object is obtained resides in the employment of a discharge device of the so-called "gas-filled" or "trigger" type in conjunction with a nonvariable phase shifting network so constructed as to effect a 180 degree shift in phase in the incoming wave at a predetermined critical frequency.

More specifically, one embodiment of the invention resides in a receiving arrangement for supervision, ringing, and other signaling purposes, over telephone lines and the like which employs alternating current of a frequency within the voice range comprising a phase shift network, a gas-filled discharge device, an amplifier, a full-wave rectifier, a guard relay, and a signal relay, all so arranged and connected that at all frequencies other than said predetermined critical or signaling frequency the gas-filled device will be ionized and both said relays operated thereby closing the signal circuit at one point and opening it at another and at said critical frequency the gas-filled device will be deionized and one of said relays released thereby completing the signal circuit.

The present arrangement which employs the phase shift-frequency characteristic of a network has a considerable advantage over previous systems employing resonant circuits or band-pass filters which depend upon an attenuation frequency characteristic.

To secure sharp discrimination between frequencies differing by a small percentage, on the latter basis, requires the use of low loss coils and condensers having a high ratio of reactance to resistance. Such coils are of necessity large and expensive. However, by utilizing the phase shift-frequency characteristic it becomes possible to employ coils of relatively high resistance because of the sudden change in current when the relative grid and anode phase shift a few degrees past 180 degrees.

The invention will be understood from the following description when read in connection with the accompanying drawing.

Fig. 1 shows a signaling system in accordance with the above-mentioned specific embodiment employing a phase shift network and a single gas-filled discharge device arranged to display a signal only when alternating current is being transmitted over the line at the predetermined critical frequency alone or in combination with other frequencies.

Fig. 2 shows another embodiment of the invention in which two gas-filled devices are used together with a phase shifting network so arranged that the control electrode of one device is subjected to the frequency flowing in the line without phase displacement, whereas the other control electrode is subjected to a wave which has been displaced in phase with respect to the other control electrode supply by passing the line frequency through a phase shifting network. In this case the output of the phase network is reversed or transposed in order that when one wave is displaced 180 degrees with respect to the other any two simultaneous half waves will be of the same sign and hence both control electrodes will at any instant be at the same potential.

Fig. 3 graphically shows the per cent of maximum average anode current passed by the gas-filled tube of Fig. 1 at different degrees by which the grid voltage lags behind the anode voltage.

Fig. 3 will be understood by referring to an article by Hull in the General Electric Review for July 1929, pages 391 to 393, which describes a general method of operating a gas discharge device (thyratron) with an alternating anode voltage and a method of controlling the average output, or anode current, thereof by varying the phase of the grid voltage with respect to that of the anode. Referring to Fig. 28 on page 393 of the foregoing publication, it will be evident that a fourth case (*d*) could be assumed in which the phase of the grid voltage, with respect to the anode voltage, is further shifted to a little more than 180 degrees whereupon current starts at the beginning of each cycle and consequently 100 per cent maximum average current flows each half cycle, this conditon continuing as the phase of the grid voltage is shifted towards 360 degrees at which point, however, the maximum average begins to decrease until it reaches a point, 180° —Φ, at which point little or no current flows, angle Φ depending on the minimum ionizing potential required for the anode.

A more complete understanding of the invention may be obtained from the following description which discusses in detail each operating step from the receiving of the incoming current signal to the operation of the relay that lights the signal lamp.

Referring now to the arrangement of Fig. 1, the line L1 is connected to the left winding of transformer 1, the right winding of which is in series with the circuit of grid element **2** of the electronic amplifying tube **3**. Line L**1** is also connected to a phase shifting network **4**, which is represented conventionally by a box without showing details since this type of apparatus is well-known in the art, it only being necessary to state that the type of network is one which exhibits little or no attenuation to current supplied thereto within the predetermined range of frequencies transmitted over the line and which causes a displacement of the phase of waves within a critical range of said transmitted frequencies of 180 degrees, and that furthermore this phase shift is continuously variable with change in frequency. Network **4** is connected to the left winding of transformer **5** the right winding of which is connected in the circuit of grid element **6** of ionic gas-filled tube **7**, which is of the so-called "hot cathode" type and is so constructed that the grid circuit can control, in general, only the starting of the anode current. Except for low anode currents the grid element of this type of ionic tube ordinarily loses control once the anode current is started. The anode element **8** of the amplifying tube **3** is in series with the left winding of transformer **9** and battery **10**. The upper right winding of transformer **9** is connected as shown to a full wave rectifier **11** which may be of the well-known copper-oxide type, or any other type with suitable characteristics. The output of this rectifier is connected to the winding of a line relay **12**. The lower right winding of transformer **9** is in series with the winding of guard relay **14** in the anode-cathode circuit of ionic gas-filled tube **7**.

Under the normal non-signaling condition on line L**1**, the frequency of the incoming current is such that the current delivered by network **4** to the left winding of transformer **5** lags in phase behind the current delivered to the left winding of transformer **1** by angles from 180 degrees to 360 degrees and from zero to 180 degrees $-\Phi$, where Φ is a small angle that depends on the minimum ionizing potential required for the anode circuit of the tube. For all angles of lag from 180 degrees to 360 degrees it has been found that the average current through the anode-cathode circuit of tube **7**, which includes the winding of relay **14**, is maintained at a constant maximum; for angles from zero to an angle less than 180 degrees by the small angle Φ aforesaid, the anode-cathode current gradually decreases from its maximum until it reaches zero. This is illustrated graphically by the curve of Fig. 3. During this non-signaling condition relays **12** and **14** are both continuously operated and consequently no circuit is closed through lamp **16**, which remains unlighted.

To signal over the line L**1**, current of a predetermined critical frequency, varying over only a small range is connected to line L**1**. This frequency is so determined that the current delivered to the grid circuit of tube **7**, which current is limited by the series resistance **24**, differs in phase from that delivered to the anode circuit of tube **7** by an angle within the range of 180 degrees and 180 degrees $-\Phi$, the angle Φ being as aforesaid. Under this condition no current flows in the anode circuit of tube **7**, relay **14** releases and a circuit is closed from ground on the contacts of relay **14**, through operated contacts of relay **12** to battery, through lamp **16**, which lights. Relay **12** is operated continuously while current is applied to line L**1**, since it is energized by the full wave rectifier **11**. As a feature of this invention, when there is no current on line L**1**, both relays **12** and **14** are then released, and the circuit through lamp **16** is open.

Referring now to the arrangement of the invention shown by Fig. 2, the line L**2** is connected through the phase shifting network **17** and the reversed conductors **18** and **19** to the left winding of the transformer **20** and directly to the left winding of the transformer **21**. The right windings of these transformers are connected in the grid circuits of the gas-filled ionic tubes **22** and **23**, which are of the hot cathode type and are similar to the tube **7** of Fig. 1. To limit the flow of current in the grid circuits resistances **37** and **38** are inserted. Normally tubes **22** and **23** are deionized due to the negative bias supplied to the grid elements **28** and **29** by the biasing batteries **39** and **40**. The anode-cathode circuits of tubes **22** and **23** are serially connected together by the conductor **25** and are in series with the winding of line relay **26** and the local source of alternating current **27**, which current should differ in frequency from that of the signaling current applied to line L**2**, the reason for which will be hereinafter given. Under the normal non-operating condition, the shifting of the phase of the incoming current due to the network **17** and its reversal over conductors **18** and **19** results in a difference in phase of the potentials applied to the grid elements **28** and **29**. Accordingly the tubes **22** and **23** can ionize simultaneously for only a part of the positive half-cycle of the incoming current, and this time of simultaneous ionization is arranged to be so small that the average current that flows through the winding of relay **26**, during the positive half-cycle of the current from source **27** is insufficient to operate relay **26**. If the frequency of the incoming current should be such that there is no shifting of phase due to the passage through the network **17**, then the reversal over conductors **15** and **16** will cause the potentials of grid elements **28** and **29** to differ in phase by 180 degrees and under this condition there will be no simultaneous ionization of tubes **22** and **23**.

When signals are transmitted over a telephone circuit, as for example in the well-known 1000 cycle ringing system employed on repeater circuit, it is necessary to use frequency selective means to discriminate between such signals and voice frequency currents from other sources. This is accomplished in part by tuning and in part by a low frequency modulation of the 1000 cycle current. Very sharply resonant circuits are unsatisfactory for this purpose owing to the fact that the side frequencies resulting from the modulation above mentioned may be excluded or attenuated. Furthermore, a circuit having very sharp tuning would exhibit large variations in response to small shifts in the signaling frequency which would result in a material increase in the cost of the signaling current supply. For these reasons it has been found preferable to utilize frequency selecting means having band pass characteristics and exhibiting a uniform response to all frequencies within a predetermined band but greatly attenuating all frequencies outside this band. The arrangements of this invention accomplish this, since operation of the signal will result for all frequencies such that the phase shift due to the network is within a range of Φ degrees extending either side 180°, wherein Φ depends on the minimum ionizing potential required by the anode. However, in some cases a wider band than this may be desired and network 17 may be so designed as to have a phase frequency characteristic adapted to produce operation of the signal device over the frequency range required by the particular signaling system to which the invention is applied. This may be accomplished by utilizing a plurality of network circuits having a constant phase shift over a range of frequencies and so combined that the resultant phase shift will be constant at 180 degrees over a predetermined band. Such a network is described in an article by O. J. Zobel in the Bell System Technical Journal for July 1928, pages 438 to 534, and more particularly as shown in Figs. 8 and 9 on pages 470 and 472, respectively. In Fig. 9 it will be noted that B_1 or B_2 exhibits substantially constant values over an appreciable range of frequencies, from 0.4 to 0.8 of the scale of frequencies used. It will therefore be apparent to one skilled in the art how a network such as 1 or 2 of Fig. 8 could be made to furnish the characteristics desired over any predetermined frequency range.

When an operator at the distant end of the line L2 connects thereto the signaling current of critical frequency, the output current from network 17 is shifted 180 degrees in phase from the input current. However, due to the reversal of current over the conductors 18 and 19 this phase shift is nullified and the current delivered to the left winding of transformer 21 is accordingly in phase with the current delivered to the left winding of transformer 20. At a phase shift of 180 degrees and its nullification by reversal it follows that the potentials applied by the right windings of transformers 20 and 21 to the grid elements 28 and 29, respectively, are substantially in phase; consequently, when from the local alternating current source 27 a positive half-cycle occurs which matches a condition of simultaneous positive potential on grid elements 28 and 29, then tubes 22 and 23 are simultaneously ionized and a current flows through the winding of relay 26, which operates and closes an obvious circuit through the line lamp 30, which lights. The circuit through the tubes may be traced from current source 27, through winding of relay 26, anode element 31, tube 22, cathode element 32, conductor 25, anode element 33, tube 23, cathode element 34 to current source 27. In order to assure that the positive half cycle from source 27 will quickly coincide with the proper grid potential for the condition of simultaneous ionization of tubes 22 and 23, the frequency of the current of source 27 differs from that of the critical signaling frequency of line L2. In practice it has been found satisfactory to use a line signaling frequency of nominally 1000 cycles per second while the frequency of the current from source 27 is nominally 800 cycles per second. The use of currents of different frequencies avoids the possibility of a delayed signal if currents of approximately the same frequency were used and these currents were in step and differed 180° in phase.

In order to apply an approximately equal amount of breakdown potential across the cathode-anode circuits of tubes 22 and 23, respectively, the equalizing shunt resistances 35 and 36 are used. These resistances are high in value, each being rated at approximately a half megohm. By using high resistances, the effect of either tube remaining conducting during a positive half-cycle of voltage from source 27, after the grid potential has dropped below the critical value required for ionization, is avoided. When a single tube only conducts under this condition the anode current is so small due to the high resistance 35 or 36 that the grid regains control as soon as it becomes more negative than the critical potential. This feature avoids the possibility that both tubes 22 and 23 might remain simultaneously ionized during a positive half-cycle from source 27, even though the grid potentials applied by the right windings of transformers 20 and 21 were sufficiently out-of-phase to effect non-simultaneous ionization and thereby properly indicate a non-signaling condition. Unless the resistances 35 and 36 are sufficiently high in magnitude so that the grid circuit can regain control as before described, it is necessary to use a frequency for current source 27, which is approximately of the same order of magnitude as that of the incoming line signaling current. On the basis of a frequency of 1000 cycles for the line current, a frequency of 800 cycles was assumed for source 27. With this frequency the time of the positive half-cycle of current from source 27 is not very much greater than that of the corresponding half cycles of grid potential from line L2. Consequently the average current through the series anode circuit of tubes 22 and 23 is not much affected by either tube remaining ionized after its grid potential is reduced below the critical value. This is due to the fact, that when the potentials applied to the grids of tubes 22 and 23 are out-of-phase under a non-signaling condition, this difference of phase measured in time is aproximately of the same order of magnitude as the time of a positive half-cycle of current from source 27. However, by using high resistances, as described hereinbefore, a current source of comparatively low frequency such as 60 cycle lighting current may be conveniently used.

In the arrangements of Figs. 1 and 2 gas-filled ionic tubes of the hot cathode type are shown. It is to be understood, however, that ionic tubes of the cold cathode double gap may be used instead of the hot cathode type without departing basically from the arrangements of the invention that have been shown. If the cold cathode type of tube is used, the control cathode takes the place of the grid element of the hot cathode tube. This type of tube is described in U. S. Patent No. 2,004,244, issued June 11, 1935 to W. H. T. Holden.

The anode supply as shown in the arrangements of Figs. 1 and 2 is from an alternating current source. It is to be understood, however, that an oscillatory type of anode circuit, supplied from a continuous current source may be used. This would effect a periodic extinguishing of the arc through the tube in the same manner as from an alternating current supply, and would permit a very high frequency of anode interruption to be used.

What is claimed is:

1. In an alternating current selective signal receiving arrangement, a signal device, means comprising a gas-filled discharge device for controlling said signal device, a source of alternating current comprisng a line, connections between said line and the input and output circuits of said discharge device and a phase shifting network included in the connection between the line and the input circuit of the discharge device so constructed that its attenuation is substantially independent of all frequencies transmitted over said line and to cause the displacement of phase of waves within a predetermined critical range of said transmitted frequencies by 180 degrees with respect to the waves within the same critical

range supplied to the output circuit of the same device.

2. In a selective signaling system, a transmission line, two signal receiving circuits associated therewith comprising a gas-filled discharge means having an input and output circuit, a connection between said line and both said input and output circuits, a phase shifting network included in one of said connections and so constructed and arranged that its attenuation is substantially independent of all frequencies within the range transmitted over said line and that an alternating current wave of a predetermined critical frequency within said range transmitted over said line will be applied to one of said signal circuits at an angle of 180 degrees with respect to the wave applied to the other circuit, said output circuit including electromagnetic relay means and a signal device controlled by said relay means.

3. In a selective signaling system, a transmission line, a signal receiving circuit associated therewith and including a gas-filled discharge device having an input circuit and an output circuit, circuit means including an amplifier for supplying anode current from said line to said discharge device, circuit means including a phase shifting network for supplying input potential from said line to said device, said network being so constructed that its attenuation is substantially independent of all frequencies within the range transmitted over said line and that an alternating current wave flowing in said line and through said network at a predetermined critical frequency within said range will be displaced 180 degrees, a signal and a circuit therefor, a guard relay energized from said line at all frequencies flowing therein, said guard relay being arranged to partially close said signal circuit and a relay in the output circuit of said discharge device adapted to complete said signal circuit when no current flows in said output circuit.

4. In an alternating current selective signal receiving arrangement, a signal device, a gas-filled discharge tube, a source of alternating current comprising a line, a connection between the line and the input circuit of said tube, a phase shifting network included in said connection, said network being so constructed and arranged that its attenuation is substantially independent of all frequencies within the range transmitted over said line and that a wave of predetermined critical frequency within said range transmitted therethrough will be displaced 180 degrees from the angle of the applied wave, and means also controlled by said line current without phase displacement, said means cooperating with said tube to operate said signal device when the frequency of the line current lies within a predetermined critical range.

5. In an alternating current selective signal receiving arrangement, a line having two branches, a phase shifting network included in one of said branches so constructed and arranged that its attenuation to the frequencies applied thereto is substantially independent of frequency and that within a predetermined critical range of said frequencies the applied wave will be displaced by 180 degrees with respect to the waves of the same frequency in the other branch, an electron discharge device supplied by each branch and a circuit, including a signal device, associated with the output circuit of said discharge devices in such a manner that the circuit will be closed to operate said signal device only when the input circuits of said discharge devices have a predetermined phase relation.

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