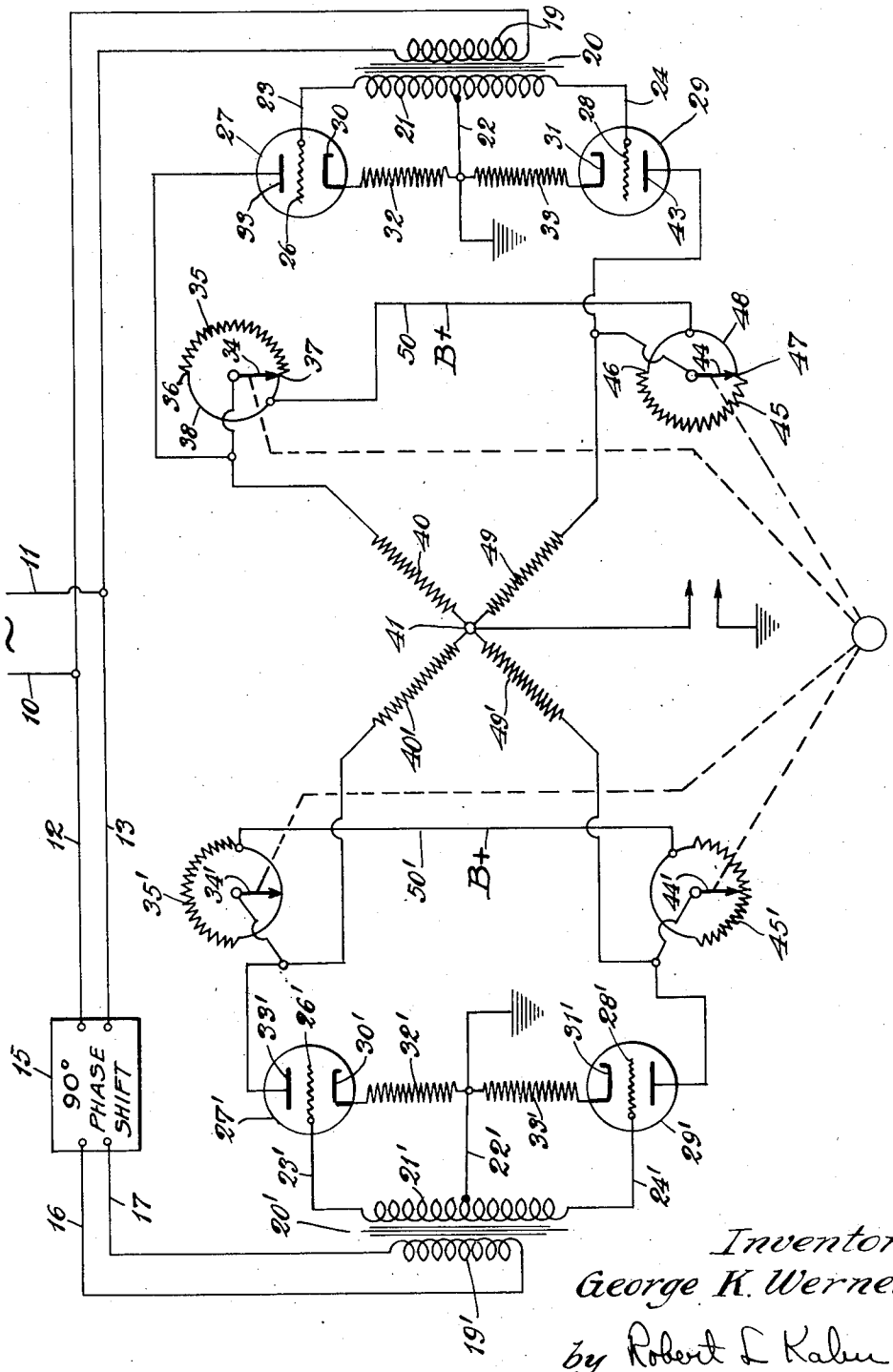
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VARIABLE PHASE SHIFTER

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VARIABLE PHASE SHIFTER

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This invention relates to an electrical apparatus and particularly to a variable phase shifter adapted to vary the phase angle between two currents by any desired value for any desired frequency while maintaining substantially constant amplitude. This invention is an improvement upon the phase shifter disclosed and claimed in the copending application of William H. Bussey, Ser. No. 725,764, and filed together with this application.

Phase shifters for producing a variable phase shift are well known and exist in a variety of forms. However, such shifters as a rule are characterized by relative complexity and variable output and are sensitive to frequency variation. In addition, few shifters are capable of varying the phase angle beyond ninety degrees. This invention provides a system which is relatively simple, economical, dependable, effective over any desired angular range to provide constant amplitude and is independent of frequency. The invention, in general, provides a plurality of variable resistors, the variation in resistors and relative values being such that effective phase shift is provided.

For a more complete understanding of the invention, reference will now be made to the drawing wherein an exemplary embodiment is shown.

Leads 10 and 11 are supplied with alternating current at any desired frequency from which another current at a desired phase angle is to be obtained. Leads 10 and 11 are connected to leads 12 and 13 respectively. Leads 12 and 13 supply ninety degree phase shift means 15, it being understood that the phase shift is fixed. Inasmuch as means for obtaining a ninety degree phase shift are well known in the art, a detailed description thereof is deemed to be unnecessary. In general, such means comprise a combination of capacitance and resistance, although other means are well known. Phase shifter 15 supplies its output to leads 16 and 17.

Leads 12 and 13, on the one hand, and 16 and 17, on the other hand, supply currents at equal potentials to primaries 19 and 19' of transformers 20 and 20' respectively. The transformers have secondaries 21 and 21', each provided with center taps 22 and 22'. Secondaries 21 and 21' have terminals 23 and 23', on the one hand, and 24 and 24', on the other hand. Terminals 23 and 23' go to control grids 26 and 26' of vacuum tubes 27 and 27' respectively. Similarly, terminals 24 and 24' are connected to control grids 28 and 28' of vacuum tubes 29 and 29' respectively. Tubes 27 and 29 are arranged to form a push-pull amplifier. Similarly, tubes 27' and 29' are arranged for push-pull operation. Vacuum tubes 27 and 29 have their cathodes 30 and 31 connected to ground through bias resistors 32 and 33. Center tap 22 is also grounded. Similarly, vacuum tubes 27' and 29' have cathodes 30' and 31' connected through grounded bias resistors 32' and 33'. Center tap 22' is also grounded. The cathode-bias resistors have a value high in comparison to normal cathode-bias resistors so that the vacuum tube functions substantially as a constant current device.

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Vacuum tube 27 has anode 33 connected to wiper 34 cooperating with resistor 35. Resistor 35 has terminals 36 and 37 short-circuited by wire 38. Wiper 34 is also connected through resistor 40 to junction 41.

Vacuum tube 29 has its anode 43 connected to wiper 44 cooperating with resistor 45, the resistor having terminals 46 and 47 short-circuited by wire 48. Wiper 44 is also connected through resistor 49 to junction 41. Shorting leads 38 and 48 are connected by wire 50 to a suitable anode supply.

Vacuum tubes 27' and 29' are similarly connected to the corresponding primed parts.

Resistors 35, 35', 45 and 45' are all wound in such a manner as to subtend 180 degrees of arc. The resistors are so arranged that all wipers are similarly positioned in space and moved as a unit. Obviously, it is immaterial whether a wiper plays over the shorting lead, although a continuous circuit from a wiper to a resistor terminal is necessary at all times. Thus, as shown, the wipers are pointing downwardly. The resistors are staggered, resistors 35 and 45 being 180 degrees out of phase. Similarly, resistors 35' and 45' are each 180 degrees out of phase with each other. Resistors 35' and 35 are 90 degrees out of phase with respect to each other. All wipers are connected together to a common actuating handle so that they may be turned simultaneously through equal angles. The wipers maintain contact with resistors or shorting leads at all times.

It is understood that the resistors may be aligned in space, and the wipers displaced in phase.

In order to obtain desirable phase shifting, it is desirable that resistors 35 or the corresponding other resistors be small in comparison to the remaining resistors in the respective circuits. Thus, resistor 35 should have a value small in comparison to load resistor 40. The same applies to resistors 35', 45 and 45' and their

respective circuit load resistors 40', 49 and 49'. It is understood that the potentials at terminals 23 and 24, on the one hand, and terminals 23' and 24', on the other hand, are equal although displaced in phase by 90 degrees.

The output of the system may be taken from junction 41 with respect to ground and provide an alternating current whose phase with respect to the currents in leads 10 and 11 may be varied smoothly from zero through 360 degrees while maintaining a substantially constant peak potential. The operation of the system is based upon the fact that a short-circuited semi-circular resistor such as 35, when energized with a substantially constant current, will provide a potential variation whose value closely approximates a sine function, the angle corresponding to the sine being the angle of wiper 34 from a zero position. The zero position is shown by wiper 34 or 44, this being at the terminal of the resistor, although wiper 34' is effectively at zero.

It is understood, of course, that resistors 35, 45, and the primed resistors corresponding thereto may be disposed on a straight form and the wipers move in a straight line. It is easier, however, to consider the operation thereof in terms of circular arc.

While the outputs of the various resistors are shown as combined into one output terminal 41 through the use of fixed resistors, it is understood that other means for combining potentials may be used. Thus, wiper 34 and wiper 44, as one pair, may have their outputs combined through resistors 40 and 49 as shown to provide one output terminal going to the input of a vacuum tube amplifier. Similarly, wipers 34' and 44' may have their outputs combined through resistors 40' and 49' and the combined outputs fed into the input circuit of another amplifier. The outputs of the two amplifiers may then be combined by connecting the anodes together. It is also possible to provide individual amplifiers for each wiper and combine the amplified outputs in any one of several well-known manners, such as by transformers or the like.

What is claimed is:

1. A continuously variable phase shifter having a substantially constant amplitude at the output, said shifter comprising a pair of vacuum tubes arranged to form a push-pull amplifier and having inputs and outputs, a short-circuited resistor for each vacuum tube, a wiper cooperating with each resistor to form a potentiometer, means for connecting the output of each vacuum tube to the wiper, a source of anode potential connected to the short-circuited ends of each of said resistors, each short-circuited resistor being disposed to provide a range of travel over which the cooperating wiper may move, said range of travel corresponding to 180 degrees of arc, one potentiometer being arranged so that it is 180 degrees out of phase with the other, a second push-pull amplifier and pair of short-circuited resistors and cooperating wipers similarly arranged and connected, the potentiometers of the first push-pull amplifier being respectively 90 degrees out of phase with the potentiometers of the other push-pull amplifier, means for moving all wipers simultaneously, means for supplying alternating potentials to the input of one push-pull amplifier, means for supplying similar alternating potentials but 90 degrees out of phase to the input of the other push-pull amplifier and means for combining the potentials from the four wipers into one output potential.

2. A continuously variable phase shifter having a substantially constant amplitude at the output, said phase shifter comprising a pair of vacuum tubes connected to form a push-pull amplifier, said amplifier having input and output circuits respectively, a short-circuited resistor in the output circuit of each tube, each resistor subtending an angle of 180 degrees, a wiper movable over the 180 degrees and contacting the resistor to form a potentiometer, a connection between a wiper and output of each tube, means for operating each vacuum tube in such a manner that the current through each tube and resistor is substantially constant in all positions of the wiper, means for connecting a source of anode potential to the terminals of said two resistors, means for disposing said two potentiometers so that one is 180 degrees out of phase with respect to the other, a second push-pull system having short-circuited resistors and wipers arranged 180 degrees out of phase with respect to each other, one potentiometer in the second group being 90 degrees out of phase with respect to the potentiometers of the first group, means for mechanically moving all wipers as a unit, means for combining the potentials at the anodes of all tubes to form an output potential with reference to the common cathode connections, and means for energizing the two push-pull amplifiers with alternating currents 90 degrees out of phase with each other.

3. The system of claim 2 wherein said means for combining said potentials comprise resistors connecting the anode of each tube to the output terminal, said resistors having a value high in comparison to a short-circuited resistor.

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